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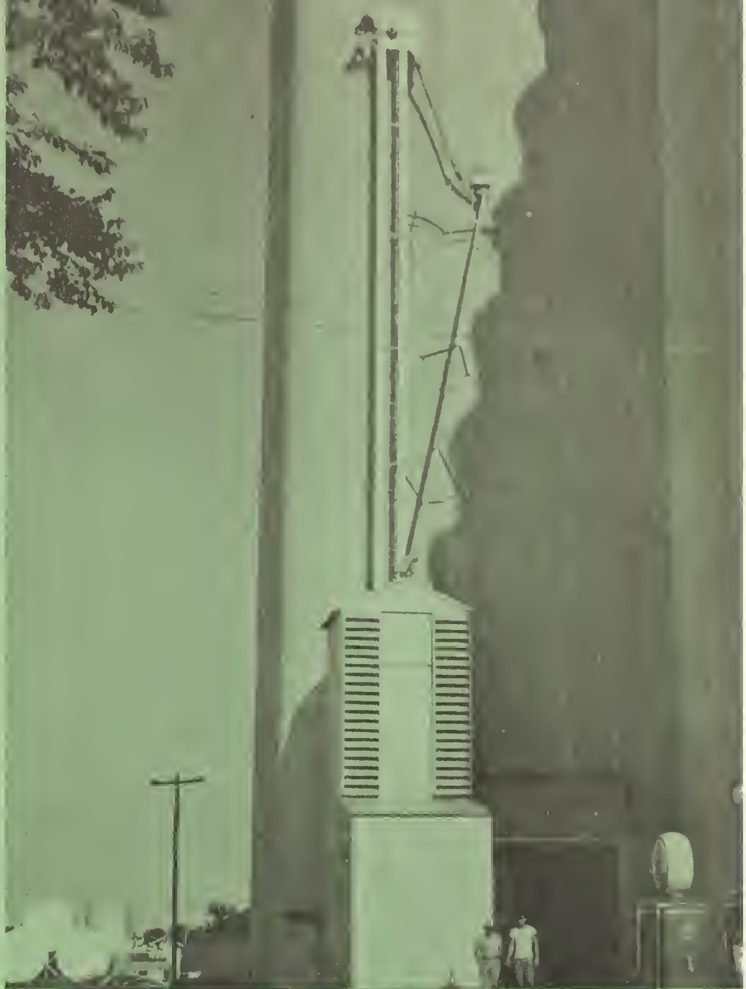


Economics of Grain Drying at Kansas Local Elevators

by J. C. Eiland and L. Orlo Sorenson

Farmer Cooperative Service
in cooperation with
Agricultural Marketing Service
United States Department of Agriculture

FARMER COOPERATIVE SERVICE
U. S. DEPARTMENT OF AGRICULTURE
WASHINGTON 25, D. C.

Joseph G. Knapp, Administrator

The Farmer Cooperative Service conducts research studies and service activities of assistance to farmers in connection with cooperatives engaged in marketing farm products, purchasing farm supplies, and supplying business services. The work of the Service relates to problems of management, organization, policies, financing, merchandising, product quality, costs, efficiency, and membership.

The Service publishes the results of such studies; confers and advises with officials of farmer cooperatives; and works with educational agencies, cooperatives, and others in the dissemination of information relating to cooperative principles and practices.

This is a joint study by Kansas State University and Farmer Cooperative Service. Thus, in addition to being listed as USDA Marketing Research Report 449, the Department of Agricultural Economics, Kansas Agricultural Experiment Station, Manhattan, also lists it as their contribution No. 343.

This study was conducted under authority of the Agricultural Marketing Act of 1946 (RMA, Title II).

Contents

Highlights

Evidence indicates that grain quality and dry matter weight are highest when grain is harvested before natural field-drying has reduced its moisture content to a safe level for extended storage.

Because of this and other factors, farmers are harvesting earlier and elevators are faced with the problem of handling and disposing of larger quantities of wet grain. Thus, elevator management is turning to the use of mechanical, heated-air grain dryers to dry and dispose of wet grain.

Farmer Cooperative Service and Kansas State University made a detailed study of grain drying operations at 11 Kansas local elevators to get more information on practices and costs. Direct drying costs were collected and analyzed for 10 drying operations for the period August 1957 through July 1958.

One purpose of the study was to develop and analyze budgeted direct drying costs for the four sizes and types of dryers most frequently used in Kansas. Budgeted costs were based on specific operating conditions and actual cost data collected from the 10 dryer operations studied. By taking into consideration the operating conditions specified, dryer operators can make comparisons between their direct drying costs and these budgeted costs for their particular size dryer to see whether opportunities exist for increasing their economic efficiency.

This report also discusses operating practices and factors affecting an elevator's decision of whether to add grain drying to its services. The benefit to the farmer and the elevator must be weighed against expected costs under local conditions by the individual elevator in deciding whether a drying operation is a desirable addition. A discussion of operating practices and other factors that influence costs also will be of interest to those now operating dryers in helping them become better established.

During the year studied the 10 elevators dried 3,250,705 bushels of grain -- 36 percent of their total receipts. Moisture content was reduced from an average of 16.3 percent to 12.6 percent. Batch and continuous-flow dryers were used.

Grain drying costs consisted of direct costs of owning and operating a dryer and indirect costs of shrinkage of the grain weight in drying and any loss in grain quality caused by the drying operation.

Direct costs were classified as (1) ownership or fixed, and (2) current operating or variable. Fixed costs included depreciation, taxes, interest on invested capital, and insurance. These totals did not change with changes in volume of grain dried. Variable costs included labor, repairs and maintenance, fuel, electric power, and administrative costs. These totals varied as the grain

volume dried varied. Shrinkage costs resulted from moisture and other grain weight loss in drying.

Average direct costs in 1957-58 realized by the 10 dryers studied amounted to 1.47 cents per bushel of grain dried, reducing the moisture as given above. Indirect costs of shrinkage averaged 4.09 cents a bushel. Together direct costs and shrinkage costs averaged 5.56 cents a bushel. Since these averages included wide variations of dryer size, volume dried, and other factors influencing costs, they were not used in the detailed analysis.

Budgeted direct costs were used in the analysis. Budgeting permits elimination of variations in volume dried, price of input items, amount of labor required, kind of fuel used, and other managerial factors whose variations are not affected by the dryer used. Under operating conditions specified in this report, ranges in budgeted per-bushel direct drying costs for four popular sizes and types of dryers, when annual volumes of grain dried by each ranged from 10,000 to 400,000 bushels, were as follows:

500 bushel batch dryer -- 9.86 to 1.19 cents

150 bushel continuous-flow dryer -- 14.15 to 1.42 cents

300 bushel continuous-flow dryer -- 17.81 to 1.43 cents

600 bushel continuous-flow dryer -- 28.07 to 1.45 cents

The reduction in per-bushel direct costs was almost completely due to the spreading of fixed costs over a larger volume of grain. For example, the range in fixed costs per bushel for the 600-bushel dryer in the example above was from 27.21 to 0.68 cents, while at the same time, variable costs ranged from only 0.86 to 0.77 cents a bushel.

Thus, as direct costs were reduced with a higher volume dried, the percentage fixed costs were of total direct costs decreased and the percentage variable costs increased.

The study showed installation and layout were more important to direct costs than the type of dryer. The dryer should be readily accessible to elevator facilities but should not interfere with other operations. Careful compliance with fire safety requirements helps keep insurance rates and costs low.

In addition to planning a dryer installation that will promote easy, efficient operations, management needs to consider details relating to shrinkage, moisture discounts, the relationship between direct drying costs and drying charges, and quality and other problems of marketing artifically dried grain. To properly reflect direct costs require knowing the rate of drying in relation to original moisture content of the grain and having a good estimate of the annual volume to be dried since this volume has an important influence on direct drying costs per bushel.

How well grain quality was maintained during the drying process and the value of grain weight loss in drying influenced total drying costs. Loss in quality added to indirect drying costs by reducing the value of the grain; whereas gain in quality increased the value of the grain and reduced these costs.

Indirect costs associated with shrinkage are determined by the amount of moisture and other weight losses in drying and by the price of dry grain.

Shrinkage costs rise with increases in weight loss and with increases in dry-grain prices. When grain is dried excessively, whether in the field or at the dryer, shrinkage is greater than necessary and usually the owner of the grain takes a loss in receipts. For example, a bushel of grain of 13 percent moisture content selling for $1 a bushel as dry grain would be worth only 96.66 cents when dried to 10 percent moisture content.

An elevator management's decision to install a grain dryer may be as important to local farmers as to the elevator. Being able to have grain dried that they intentionally harvest wet means that farmers can harvest earlier, thus possibly saving more grain. This frees land earlier for other uses, and also gives farmers more latitude in storing and marketing their grain to advantage. For example, at times during the wheat harvest season of 1958, the net loan rate at Kansas City exceeded the cash price a maximum of 33 cents a bushel -- an advantage that is reflected to the local elevator.

Management should also bear in mind that if the demand for drying services is significant, an elevator can probably increase the volume of its other business by installing a grain dryer. Farmers are likely to patronize an elevator that meets several of their needs, rather than one with limited services.

Determining whether the community as a whole would show economic gains as a result of grain drying operations involves many factors that defy measurement. However, estimates of present grain harvesting losses and amounts that could be saved by earlier harvesting and mechanical drying indicate there would be general economic gains if harvesting could be done at the ideal time to save and preserve the most grain of the highest quality.

Economics of Grain Drying at Kansas Local Elevators

by J. C. Eiland and L. Orlo Sorenson [1]

More than ever before, farmers today are harvesting grain of moisture content too high to permit safe storage. There are several reasons for this.

Research studies are finding that quality is highest when grain is harvested before natural field drying has reduced moisture content to safe storage levels. Today's harvesting machinery is able to recover more of the grain when it is harvested with moisture content too high for safe storage. Insect, weather, and related losses are reduced by early harvest because of the shorter time the grain is exposed. And today's farming practices contribute to the farmer's inclination to harvest his crops earlier.

However, this trend toward earlier harvesting can go only as fast and as far as will be permitted by the grain trade's ability and willingness to develop and adopt methods of handling wet grain economically while preserving its basic quality. Many elevator operators have followed the practice of blending wet and subdry [2] grain so that the average moisture is within the safe storage range. Turning the grain by dropping from overhead bins and re-elevation has been another method used in managing limited amounts of wet grain. Some has been shipped wet at discounted prices.

Drying grain artificially is a newer and increasingly popular method of disposing of wet grain. This method has some limitations and problems, but it permits a local elevator to handle a larger volume of wet grain than it could handle otherwise.

The increasing number of mechanical dryers being used by Kansas elevators pointed up the need for an economic study of their practices, costs, advantages, and disadvantages. An earlier report [3] presented results of a survey, made jointly by Farmer Cooperative Service and Kansas State University, of all Kansas elevators with dryers in August 1957. That report described

[1] Since this study was completed, Mr. Eiland transferred from the Marketing Division of the Farmer Cooperative Service to the Marketing Economics Research Division, Agricultural Marketing Service. Mr. L. Orlo Sorenson is with Department of Agricultural Economics, Kansas State University.

[2] In this report, "wet" grain is grain with moisture content above the level generally accepted by Kansas elevators for safe storage, and "subdry" grain is grain with moisture content below that level. Most Kansas grains of moisture content above 13 percent are termed "wet"; below 13 percent, "subdry".

[3] Sorenson, L. Orlo, and Eiland, J. C., Drying Grain at Kansas Local Elevators, Kansas State College, (now Kansas State University), Agricultural Economics Report 83, November 1958.

Note: Appreciation is expressed to the management of the elevators who provided information for this study and to Stanley K. Thurston, formerly with the Grain Branch, Farmer Cooperative Service, and now with the Sugar Division, Commodity Stabilization Service, for helping guide the study in its early phases.

artificial drying and included a brief discussion of costs. Its emphasis was on general management considerations.

This report is based on data collected from 11 local elevators, nine of them cooperatives, included in the original survey. It analyzes costs, factors affecting costs, and returns from drying grain. Sizes and types of dryers, and layouts and installations are discussed, as well as the farmer's problems in deciding whether to harvest wet grain and the elevator's problems in deciding how to dispose of it.

Elevator operators contemplating installing dryers will find the information in this report helpful. It will also be useful to elevators now providing grain drying services and wishing to increase their efficiency.

Scope of Study

A major objective of this phase of the grain drying study was to develop a set of representative or budgeted cost figures for the four sizes or types of dryers most commonly used in Kansas. This required more comprehensive data than were collected in the original survey.

Local elevators to be studied in detail were carefully selected to provide coverage of extreme variations existing in elevator operations in Kansas. Well distributed geographically, they represent different types of farming areas, ranging from the general type farming areas in eastern Kansas with more variation in kinds of grain grown to the cash-grain wheat and sorghum areas of western Kansas.

Types of elevator facilities, size of operations, and types and sizes of dryers also were considered in selecting the elevators to be studied.

Data covering the 12-month period August 1957 through July 1958 were requested from 11 elevators, nine of them cooperatives. One elevator did not have complete cost records but furnished the other information requested. Ten supplied detailed cost data, including daily drying reports showing volume of grain dried by kind, hours of dryer operation, and original and final moisture content. Also, six elevators that had been drying grain since 1953 furnished general data for the years 1953 through 1957.

The percentage of grain receipts dried increased enormously in 1957 compared with previous years (figure 1). Sorghum grain ranked first, followed by corn and wheat.

During the study year, the 10 elevators with complete data received 9,001,317 bushels of grain and dried 3,250,705 bushels (table 1). In terms of bushels dried, sorghum grain, wheat, and corn were most important in that order.

Original moisture content of grain and the amount of moisture removed are important factors in drying costs. Table 2 shows the kinds, amounts, and the average original and final moisture content of grain dried at the 10 elevators in the year ending July 1958. Average moisture reduction was from 16.3 to 12.6 percent.

The size and type of dryer also affect drying costs (costs of owning and operating a dryer, excluding shrinkage

Figure 1

Percentages of Annual Grain Receipts Dried at 6 Kansas Local Elevators That Had Dryers, 1953-57 and at 10 Elevators, August 1957-July 1958

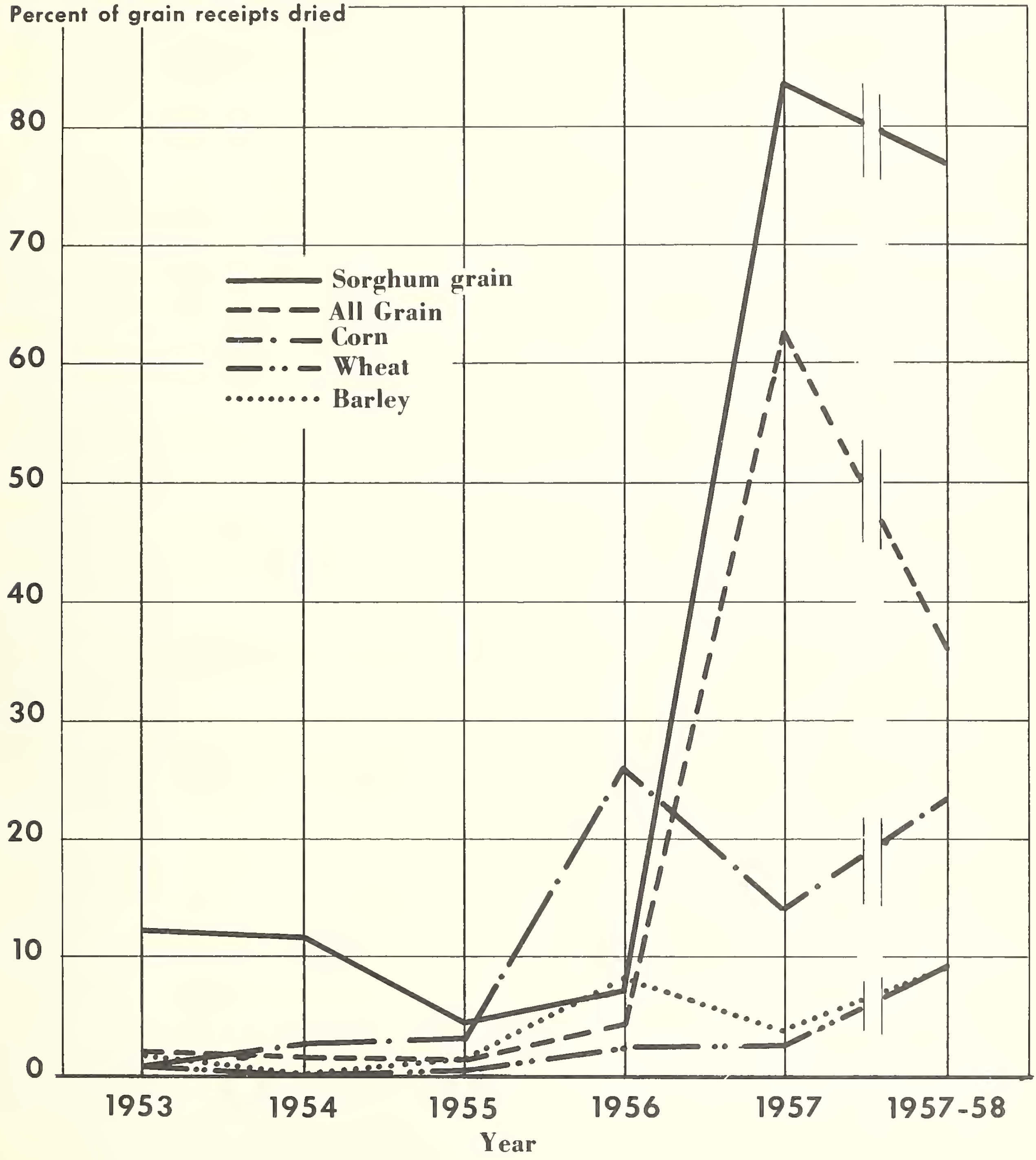


Table 1. - *Grain received[1] and dried at 10 Kansas local elevators, August 1957 July 1958*

Kind of grain	Amount of grain		
	Received	Dried	
	Bushels	*Bushels*	*Percent*
Wheat	4,785,719	452,025	9.4
Corn	461,950	107,194	23.2
Sorghum grain	3,468,494	2,671,993	77.0
Barley	205,999	18,643	9.0
Oats	69,661	500	0.7
Rye	9,494	350	3.7
Total	9,001,317	3,250,705	36.1
Average per elevator	900,132	325,070	-

[1]Does not include minor quantities of soybeans since none were dried.

costs). The elevators studied were using four types or sizes of dryers -- 500 bushel batch; and small, medium, and large continuous flow. Some of the large dryers operated at lower costs per bushel of grain dried than did smaller dryers. This was primarily because they operated about twice as many hours, dried a greater volume of grain relative to their size, and did not reduce moisture content as much. Direct drying costs per hour and per bushel, by types and size of dryer along with approximate hours of dryer operation August 1957 through July 1958, appear in table 3.

Table 2. - *Kinds, amounts, and moisture content of grain dried at 10 Kansas local elevators, August 1957 - July 1958*

Kind of grain	Amounts dried[1]		Average[2] moisture content	
	Total	Percent of total volume of all grain dried	Original	Final
	Bushels	*Percent*	*Percent*	*Percent*
Wheat	452,025	13.9	15.9	12.7
Corn	107,194	3.3	17.7	12.8
Sorghum grain	2,671,993	82.2	16.4	12.6
Barley	18,643	0.6	16.0	11.8
Oats	500	(3)	16.5	12.2
Rye	350	(3)	16.0	13.0
Total	3,250,705	100.0	-	-
Average per elevator	325,070	-	16.3	12.6

[1]Bushels before dried.
[2]Weighted by bushels.
[3]Less than 0.05 of 1 percent.

Table 3. - *Direct drying costs per hour and per bushel, by type and size dryer, at 10 Kansas local elevators August 1957 - July 1958*

Number and type of dryers	Rated capacity per hour[1]	Time of operation		Time or annual capacity utilized[3]	Grain dried[4]	Direct drying costs		
		Total[2]	Per dryer			Total	Per hour	Per bushel[4]
	Bushels	*Hours*	*Hours*	*Percent*	*Bushels*	*Dollars*	*Dollars*	*Cents*
3 Batch	[5]500	2,317	772	11	473,869	10,769	4.65	2.27
2 Continuous-flow	[6]125	1,381	690	10	230,747	5,056	3.66	2.19
3 Continuous-flow	300	3,243	1,081	15	739,189	15,212	4.69	2.06
2 Continuous-flow	600	3,944	1,972	27	1,806,900	16,837	4.27	0.93
Total		10,885			3,250,705	47,874		
Average		1,088			325,070	4,787	4.40	1.47

[1]Based on drying corn, dropping the moisture about 5 percentage points.
[2]Partially estimated.
[3]Annual capacity is based on 7,200 hours of potential drying time (6 days a week, for 50 weeks a year, at 24 hours a day).
[4]Bushels before dried.
[5]Holding capacity.
[6]Average.

Note: For variations in moisture content of grain dried by type and size dryer, refer to appendix table 2.

Numerous factors besides volume and type of grain dried, kind of dryer, and moisture content influence direct drying costs. These include wage rates, prices paid for input items, management practices, and even weather conditions.

To develop grain drying cost figures that would be comparable and meaningful on an industry-wide basis, it was necessary to eliminate as many as possible of these variable factors. This was done by assuming specific operating conditions, defining terms, and then using the data furnished by the study elevators to project budgeted costs for various volumes and types of dryers under these stated conditions. The budgeted costs so derived are discussed and analyzed in the following section. Any dryer operator can compare and adjust them to his own operating situation.

The actual cost and operating figures gathered for this report naturally reflect practices and conditions at the particular elevators studied and are influenced by all the variable factors mentioned in the preceding paragraphs. Averages of these actual costs would be of little value to other elevator operators for purposes of comparison as they would not represent any specific size dryer or any specific conditions, other than the moisture removal. However, data in table 3 and in the appendix have been included to show the actual cost and operating figures on which the budgeted figures were based.

Appendix table 1 shows average cost of drying 325,000 bushels of grain per dryer at the 10 local elevators studied, and projected average costs for drying other volumes. The moisture content and volume of grain dried and the drying rate are shown, by type of dryer, in appendix table 2.

Budgeted Direct Costs of Drying Grain

This section of the report analyzes budgeted direct drying costs for both batch and continuous-flow dryers in the four sizes most commonly used in Kansas. In calculating these budgeted costs, four general assumptions were made to adjust and stabilize factors which normally cause variations in drying costs.

First, and possibly the most important single assumption is that the amount of moisture removed and the combinations of kinds of grain dried at these elevators in 1957-58 were representative of other years and other volumes. Budgeted costs were based on data given in tables 2 and 3, and appendix table 2 with respect to kinds and amounts of grain dried and moisture reduction.

Second, representative prices paid by the study elevators in 1957-58 for input items were the best basis available to use as a price standard in calculating budgeted costs. Wage rates and prices may be different at a particular location.

Third, the study showed that management had made no clear determination of labor requirements for dryer operations. There appeared to be no appreciable difference in labor used that could be attributed to dryer size alone, although some operators with small dryers estimated labor requirements per hour of drying time higher than did other operators with larger dryers. This we attributed to differences in practices and methods of labor allocation and not to size of dryer. In calculating labor costs it was therefore assumed that labor used per hour of dryer operation would be the same for the different types and sizes of dryers when they were operated under comparable conditions.

Fourth, grain drying operations were regarded as supplementary to elevator operations and were not treated as a separate department. General elevator overhead costs such as office and management expense were not charged to drying costs, except as time could be charged directly to activities resulting from drying. Drying operations did require some time from management and office personnel. These were calculated as variable costs.

Any elevator management considering installing a grain dryer and concerned about the direct operating costs and the economic advantages and disadvantages of adding this service should find these budgeted costs helpful. Any elevator operator now providing drying service can compare these budgeted costs with his cost figures. He may possibly discover that some of his costs are high and can be reduced, thus improving drying efficiency.

In using these budgeted costs as a guide or measuring stick, it is important to keep in mind that they do not precisely represent any dryer studied and also that they apply only under the conditions assumed and described.

Cost Items by Volume and Size of Dryer

Direct costs of drying grain are classified as (1) ownership or fixed, and (2) current operating or variable. Ownership or fixed costs include depreciation, taxes, interest on capital invested, and insurance. Direct labor, repairs and maintenance, fuel, electric power, and administrative costs are classed as current operating or variable costs.

Total annual costs for items in the ownership or fixed costs category usually are committed or can be calculated in advance. The total amount of these costs is the same regardless of the volume of grain dried. For example, doubling the volume of grain dried would have no effect on the total amount of taxes and insurance; cutting the volume in half likewise would have no effect.

However, when figured on a <u>per-bushel</u> basis, these fixed costs vary indirectly in proportion to the number of bushels dried. If the volume of grain dried annually is doubled, the per bushel costs of fixed or ownership items are cut in half.

Unlike fixed costs, the total amount of variable costs changes with the volume of grain dried. That is, variable costs rise or fall as grain volume rises or falls and in almost or slightly less than the same proportion, provided moisture reduction is the same. Figure 2 shows the budgeted per-bushel direct costs of drying various annual volumes of grain using a 300-bushel continuous-flow dryer.

The percentages of total drying costs represented by fixed and variable costs also vary with the annual volume of grain dried. For example, if the average annual volume of grain dried at Kansas elevators had amounted to only 16,250 bushels, fixed costs would have represented about 90 percent and variable costs about 10 percent of the total.

On the other hand, if a million bushels of grain had been dried annually, about 14 percent of the direct costs would have been fixed and 86 percent variable. The relationship between fixed and variable budgeted costs per bushel, at different annual volumes using a 300-bushel continuous-flow dryer, is shown in figure 3.

Figures 2 and 3 apply to a 300-bushel continuous-flow dryer. However, the same general relationships between fixed and variable costs would apply for other size and type dryers.

In tables 4 through 7, budgeted direct costs are given by item for various annual volumes of grain dried and for four different dryers. Total and per bushel costs are given for each item. Following the tables is a discussion of these individual cost items. The tables are given first so that you can refer to them easily in connection with the analysis that follows.

Again, keep in mind that a multitude of factors can cause variations in actual costs. These budgeted costs relate only to the situations described, which are most representative of drying operations included in this study. It is also assumed that the specified volumes could be dried without adding drying capacity or hiring additional personnel.

Ownership or Fixed Costs

As mentioned earlier in this section, the fixed or ownership costs of operating a grain dryer include four major items: Depreciation, taxes, insurance, and interest on money invested.

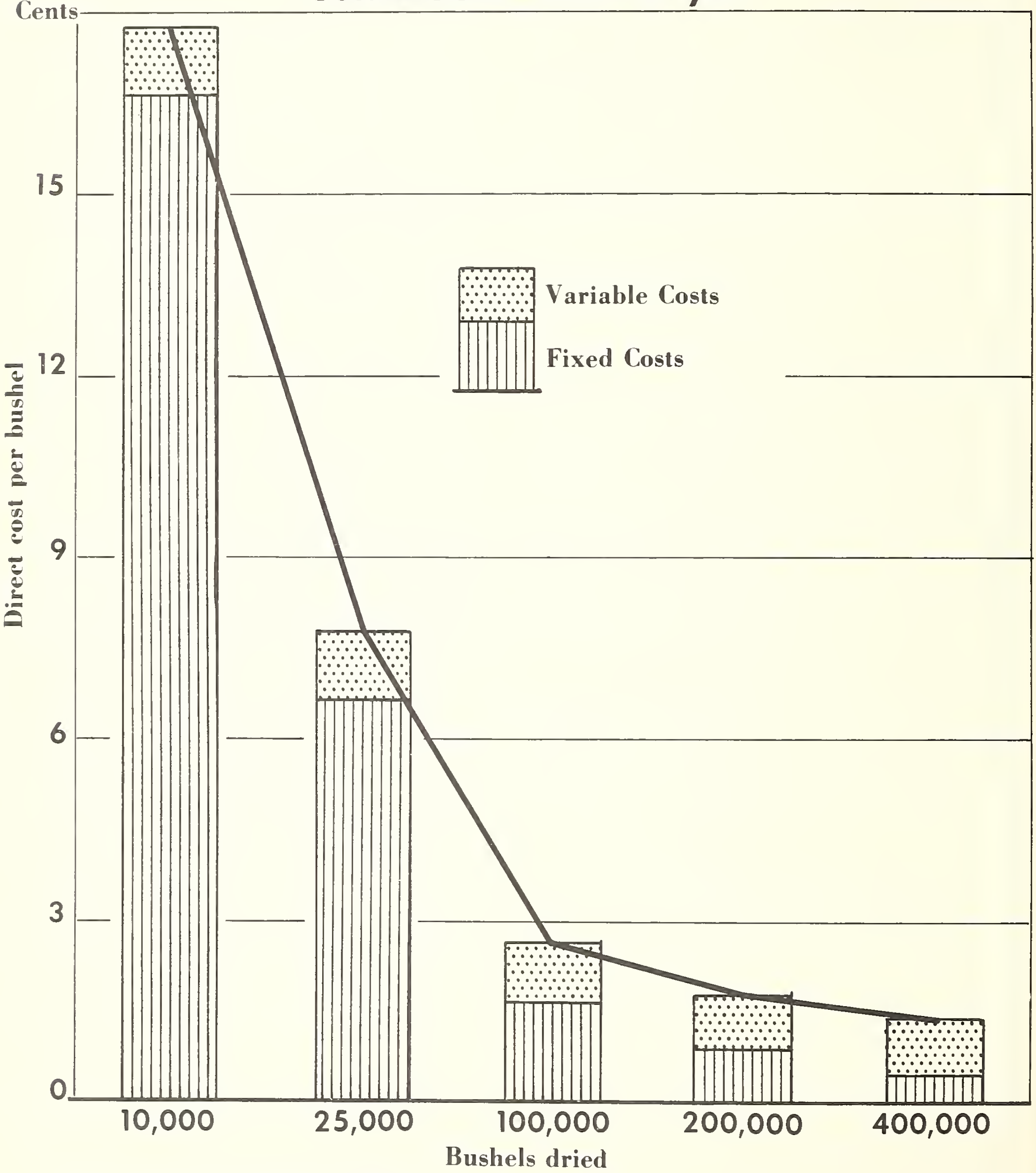
<u>Depreciation</u>. - The total amount budgeted annually for depreciation is dependent upon two factors:

1. Original installed cost of the dryer.

2. Length of useful life of the dryer. The useful life of a grain dryer, allowed by Internal Revenue Service for tax purposes, is 12 years. This figure was

Figure 2

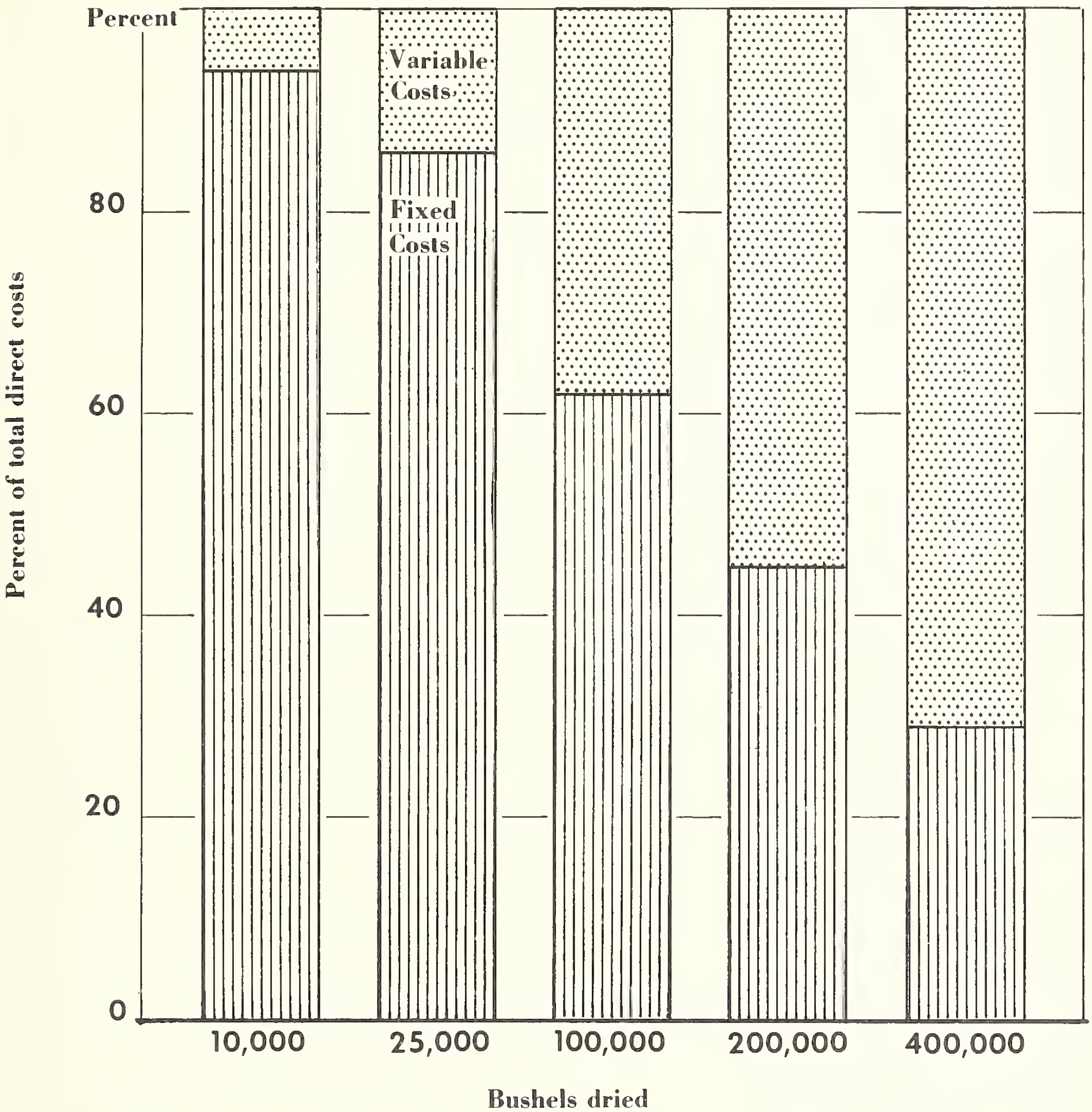
Budgeted per Bushel Direct Costs of Drying Various Annual Volumes of Grain Using a 300-Bushel Continuous-Flow Dryer



Note: Data are shown in table 6.

Figure 3

Budgeted Direct Costs of a 300-Bushel Continuous-Flow Dryer Showing the Relationship of Fixed and Variable Costs per Bushel at Different Annual Volumes of Grain Dried



Note: Data are shown in table 6

Table 4. - *Budgeted direct costs of drying various annual volumes of grain*[1] *with a 500-bushel batch-dryer*

Cost item	Direct cost of drying annual volumes of grain[1]									
	10,000 bu.		25,000 bu.		100,000 bu.		200,000 bu.		400,000 bu.	
	Total	Per bu.	Total	Per bu.	Total	Per bu.	Total	Per bu.	Total	Per bu.
	Dollars	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*
Fixed costs:										
Depreciation	583.10	5.83	583.10	2.34	583.10	0.58	583.10	0.29	583.10	0.15
Tax	56.88	0.57	56.88	0.23	56.88	0.06	56.88	0.03	56.88	0.02
Insurance	50.85	0.51	50.85	0.20	50.85	0.04	50.85	0.02	50.85	0.01
Interest	175.00	1.75	175.00	0.70	175.00	0.18	175.00	0.09	175.00	0.04
Total fixed costs	865.83	8.66	865.83	3.47	865.83	0.86	865.83	0.43	865.83	0.22
Variable costs:										
Labor	27.44	0.27	68.32	0.27	273.28	0.27	546.56	0.27	1,092.12	0.27
Repairs and maintenance	3.07	0.03	7.62	0.03	30.49	0.03	60.98	0.03	121.96	0.03
Fuel[2]	43.01	0.43	58.49	0.23	204.24	0.21	402.14	0.20	793.17	0.20
Electric power	18.10	0.18	45.11	0.18	180.44	0.18	360.88	0.18	721.40	0.18
Administrative	28.91	0.29	71.91	0.29	287.92	0.29	575.84	0.29	1,151.09	0.29
Total variable costs	120.53	1.20	251.45	1.00	976.37	0.98	1,946.40	0.97	3,879.74	0.97
Total fixed and variable costs	986.36	9.86	1,117.28	4.47	1,842.20	1.84	2,812.23	1.40	4,745.57	1.19

[1]See table 2 for proportionate amounts of different grains and appendix table 2 for beginning and ending moisture content on which these data are based.
[2]Fuel costs are based on the use of natural gas. The use of propane would cause the cost item to be higher (see appendix table 3).

Table 5. - *Budgeted direct costs of drying various annual volumes of grain*[1] *with a 150-bushel-per-hour continuous-flow dryer*[2]

Cost item	Direct cost of drying annual volumes of grain[1]									
	10,000 bu.		25,000 bu.		100,000 bu.		200,000 bu.		400,000 bu.	
	Total	Per bu.	Total	Per bu.	Total	Per bu.	Total	Per bu.	Total	Per bu.
	Dollars	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*
Fixed costs:										
Depreciation	874.65	8.75	874.65	3.50	874.65	0.88	874.65	0.44	874.65	0.22
Tax	85.31	0.85	85.31	0.34	85.31	0.08	85.31	0.04	85.31	0.02
Insurance	76.27	0.76	76.27	0.30	76.27	0.08	76.27	0.04	76.27	0.02
Interest	262.50	2.63	262.50	1.05	262.50	0.26	262.50	0.13	262.50	0.06
Total fixed costs	1,298.73	12.99	1,298.73	5.19	1,298.73	1.30	1,298.73	0.65	1,298.73	0.32
Variable costs:										
Labor	33.60	0.34	84.00	0.34	336.00	0.34	672.00	0.34	1,344.00	0.34
Repairs and maintenance	3.07	0.03	7.62	0.03	30.49	0.03	60.98	0.03	121.96	0.03
Fuel[3]	34.51	0.34	77.20	0.31	289.29	0.29	557.10	0.28	1,103.47	0.28
Electric power	9.74	0.10	24.38	0.10	97.46	0.10	194.92	0.10	389.84	0.10
Administrative	35.40	0.35	88.50	0.35	354.00	0.35	708.00	0.35	1,416.00	0.35
Total variable costs	116.32	1.16	281.70	1.13	1,107.24	1.11	2,193.00	1.10	4,375.27	1.10
Total fixed and variable costs	1,415.05	14.15	1,580.43	6.32	2,405.97	2.41	3,491.73	1.75	5,674.00	1.42

[1]See table 2 for proportionate amounts of different grains and appendix table 2 for beginning and ending moisture content on which these data are based.

[2]The small continuous-flow dryers in table 3 represent an average of dryers of 150 and 100 bushel capacity. Since there are more dryers of 150 bushel capacity in use, budgeted figures were developed for that size. Overall costs would be approximately the same for for a 100-bushel dryer.

[3]Fuel costs are based on the use of natural gas. The use of propane would cause the cost item to be higher (see appendix table 3).

Table 6. - *Budgeted direct costs of drying various annual volumes of grain*[1] *with a 300-bushel per hour continuous flow dryer*

Cost item	Direct cost of drying volumes of grain[1]									
	10,000 bu.		25,000 bu.		100,000 bu.		200,000 bu.		400,000 bu.	
	Total	Per bu.	Total	Per bu.	Total	Per bu.	Total	Per bu.	Total	Per bu.
	Dollars	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*
Fixed costs:										
Depreciation	1,124.00	11.24	1,124.00	4.50	1,124.00	1.12	1,124.00	0.56	1,124.00	0.28
Tax	109.69	1.10	109.69	0.44	109.69	0.11	109.69	0.06	109.69	0.03
Insurance	98.06	0.98	98.06	0.39	98.06	0.10	98.06	0.05	98.06	0.03
Interest	337.50	3.37	337.50	1.35	337.50	0.34	337.50	0.17	337.50	0.08
Total fixed costs	1,669.25	16.69	1,669.25	6.68	1,669.25	1.67	1,669.25	0.84	1,669.25	0.42
Variable costs:										
Labor	24.64	0.25	61.60	0.25	245.84	0.25	491.12	0.25	982.24	0.25
Repairs and maintenance	3.07	0.03	7.62	0.03	30.49	0.03	60.98	0.03	121.96	0.03
Fuel[2]	43.74	0.44	94.47	0.38	345.16	0.34	669.14	0.33	1,349.02	0.33
Electric power	14.41	0.14	35.99	0.14	143.62	0.14	286.93	0.14	573.85	0.14
Administrative	25.96	0.26	64.90	0.26	259.01	0.26	517.43	0.26	1,034.86	0.26
Total variable costs	111.82	1.12	264.58	1.06	1,024.12	1.02	2,025.60	1.01	4,061.93	1.01
Total fixed and variable costs	1,781.07	17.81	1,933.83	7.74	2,693.37	2.69	3,694.85	1.85	5,731.18	1.43

[1]See table 2 for proportionate amounts of different grains and appendix table 2 for beginning and ending moisture content on which these data are based.
[2]Fuel costs are based on the use of natural gas. The use of propane would cause the cost item to be higher (see appendix table 3).

Table 7. - *Budgeted direct costs of drying various annual volumes of grain*[1] *with a 600-bushel per hour continuous flow dryer*

Cost item	Direct cost of drying volumes of grain[1]									
	10,000 bu.		25,000 bu.		100,000 bu.		200,000 bu.		400,000 bu.	
	Total	Per bu.	Total	Per bu.	Total	Per bu.	Total	Per bu.	Total	Per bu.
	Dollars	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*
Fixed costs:										
Depreciation	1,832.60	18.32	1,832.60	7.33	1,832.60	1.83	1,832.60	0.92	1,832.60	0.46
Tax	178.75	1.79	178.75	0.72	178.75	0.18	178.75	0.09	178.75	0.04
Insurance	159.80	1.60	159.80	0.64	159.80	0.16	159.80	0.08	159.80	0.04
Interest	550.00	5.50	550.00	2.20	550.00	0.55	550.00	0.27	550.00	0.14
Total fixed costs	2,721.15	27.21	2,721.15	10.89	2,721.15	2.72	2,721.15	1.36	2,721.15	0.68
Variable costs:										
Labor	12.32	0.12	30.80	0.12	122.08	0.12	244.72	0.12	488.88	0.12
Repairs and maintenance	3.07	0.03	7.62	0.03	30.49	0.03	60.98	0.03	121.96	0.03
Fuel[2]	39.42	0.39	86.37	0.34	301.73	0.30	593.78	0.29	1,175.40	0.29
Electric power	18.56	0.19	46.41	0.19	185.64	0.19	371.28	0.19	742.56	0.19
Administrative	12.98	0.13	32.45	0.13	128.62	0.13	257.83	0.13	515.07	0.13
Total variable costs	86.35	0.86	203.65	0.81	768.56	0.77	1,528.59	0.76	3,043.87	0.76
Total fixed and variable costs	2,807.50	28.07	2,924.80	11.70	3,489.71	3.49	4,249.74	2.12	5,765.02	1.44

[1]See table 2 for proportionate amounts of different grains and appendix table 2 for beginning and ending moisture content on which these data are based.
[2]Fuel costs are based on the use of natural gas. The use of propane would cause the cost item to be higher (see appendix table 3).

used for the budgeted calculations in this report.

Taxes. - The total annual figure for taxes differs considerably by counties in Kansas. Main factors causing variations are:

1. Whether the dryer is taxed as part of the real estate or as personal property.

2. Method of assessment and rate of taxation.

Budgeted tax costs were based on average undepreciated values and a representative assessment and rate of taxation. These were found to be an assessment of 25 percent of the undepreciated or book value of the dryer, and an average tax rate of $6.50 per $100 assessed valuation.

Insurance. - Insurance is usually carried to cover risks of damage to or destruction of, facilities and grain stocks from fire, and risks under windstorm and extended coverage endorsement. Addition of a dryer may mean higher insurance rates on elevator facilities and grain stocks because of the increased fire hazards.

The annual insurance cost figure is influenced by these factors:

1. Amount of coverage and value of dryer for insurance purposes.

2. Effect on existing insurance rates and, therefore, cost figures for other plant facilities and stocks of grain.

3. Location of the dryer and fire protection offered by the community. Whether any losses occur that are not covered or are only partially covered would ultimately be reflected in insurance costs. Since these cannot be determined in advance, they were not included in the budgeted cost figures. The budgeted insurance costs were computed as follows:

1. Combined fire, windstorm and extended coverage rate of 90.8 cents per $100 of insurable value of the dryer.

2. 80 percent coverage on the installed cost of the dryer for the life of the dryer.

3. 33 cents per horsepower on dryer motors insured against burn-out and other failure.

4. An assumed rate increase of 0.6 cents per $100 of insurance on the elevator (non-combustible) and an increase of 0.5 cents of grain stocks. Based on an elevator valuation of $100,000 and grain stocks of $200,000, this would result in an average annual increase of $16.20 in these insurance costs attributable to the dryer.

Interest. - Interest on the money invested in a dryer is an economic cost regardless of whether grain is dried. This economic cost is determined by what the money would return if invested elsewhere. But if the money invested in the dryer is borrowed, the interest charged represents the cost in the sense of out-of-pocket costs. For the budgeted costs, interest was computed at 5 percent, the approximate rate paid to the bank for cooperatives for facility loans in 1957.

The amount of money invested in a dryer at any given time equals the book or undepreciated value of the dryer. Therefore, for the first year it is the installed cost of the dryer less one-half year's depreciation; for the last year of useful life of the dryer, it is the amount

of one-half year's depreciation. Consequently, the average investment for the life of the dryer is half the installed cost. Thus, the annual average budgeted interest cost figure was determined by this formula:

$$\text{Annual interest costs} = \frac{\text{Original installed cost of dryer X 5\%}}{2}$$

Current Operating or Variable Costs

Current operating or variable costs are incurred only when grain is actually being dried. The total annual figure, therefore, varies directly with the volume of grain dried. Per-bushel costs tend to be the same at all volumes of grain dried so long as other factors are unchanged.

Items included in this classification are labor, repairs and maintenance, fuel, electric power, and administrative costs.

Labor. - At the elevators studied, labor costs were found to vary according to the following factors:

1. Amount of regular man-time utilized by the dryer.

2. Wages paid.

3. Amount of overtime pay involved.

4. Whether extra employees were added during the drying season.

Other factors, such as moisture removed, were assumed to be constant.

Usually operating the dryer did not require hiring any additional help. Most grain was dried during the day and the dryer was attended by regular employees. Thus it actually provided for a fuller use of existing personnel and, in that sense, did not add to overall labor costs of elevator operation.

Data indicated that, operating a dryer during the day required about 40 percent of one man's time. Since regular hourly pay for labor averaged about \$1.40, the cost of dryer labor averaged about 56 cents an hour of daytime operation. Budgeted labor costs for all dryers were based on daytime operation at regular-time pay. Total labor cost increased in a ratio of one to one with increases in volume dried, when other factors were unchanged.

However, for night-time operation using regular help at a 50 percent increase in wage rates and with all time charged to the dryer, labor costs ran about \$2.10 an hour of drying time. If night operation required the use of temporary employees at regular pay and their labor could not be partially utilized for other elevator work, the hourly labor cost to operate the dryer ran about \$1.40. These facts should be considered in applying labor costs to a specific situation.

Repairs and Maintenance. - Age of the dryer and volume of grain dried were the most important factors influencing the annual figure for the repairs and maintenance cost item at the elevators studied. Since most of the dryers were in the early years of their useful life, these particular costs possibly were on the conservative side.

For the 10 dryers studied, repairs and maintenance costs for the year August 1957 through July 1958 averaged \$99.

Fuel. - Total fuel costs increase as the volume of grain increases. When the fuel used is natural gas, the total

cost increase is less than in a one-to-one ratio with volume of grain dried because the unit cost of the fuel decreases with higher consumption. When propane is used, the ratio is, for practical purposes, one-to-one between the total cost figure and the volume of grain dried.

Six of the dryers studied used natural gas and four operated on propane. The average fuel costs per bushel of grain dried at these elevators, August 1957 through July 1958, are given in appendix table 3. Since two-thirds of the dryers in operation in Kansas in 1957 used natural gas, budgeted fuel costs were based on its use.

Another factor that influences fuel costs is the price rate schedule. These schedules depend on locality and also the purpose for which the fuel is used. A common natural gas rate schedule for dryer operators is as follows:

Volume used	Monthly rate per 1,000 cu. ft.
First 1,000 cu. ft. (minimum)	$1.25
Next 19,000 cu. ft.	0.52
Next 30,000 cu. ft.	0.43
Excess of 50,000 cu. ft.	0.35

The atmospheric temperature when the drying is done influences the amount of fuel required and therefore fuel costs. Data collected indicated that at an atmospheric temperature of 23° F., twice as much fuel was required to operate the dryers as when the temperature was 93° F. (table 8 and figure 4).

Fuel cost calculations were projected on the basis of average hourly

Table 8. - *Variations in average hourly fuel consumption by two grain dryers of equal capacity, both operating with drying air temperatures of 180° F., when data are grouped by atmospheric temperature, August 1957 - July 1958*

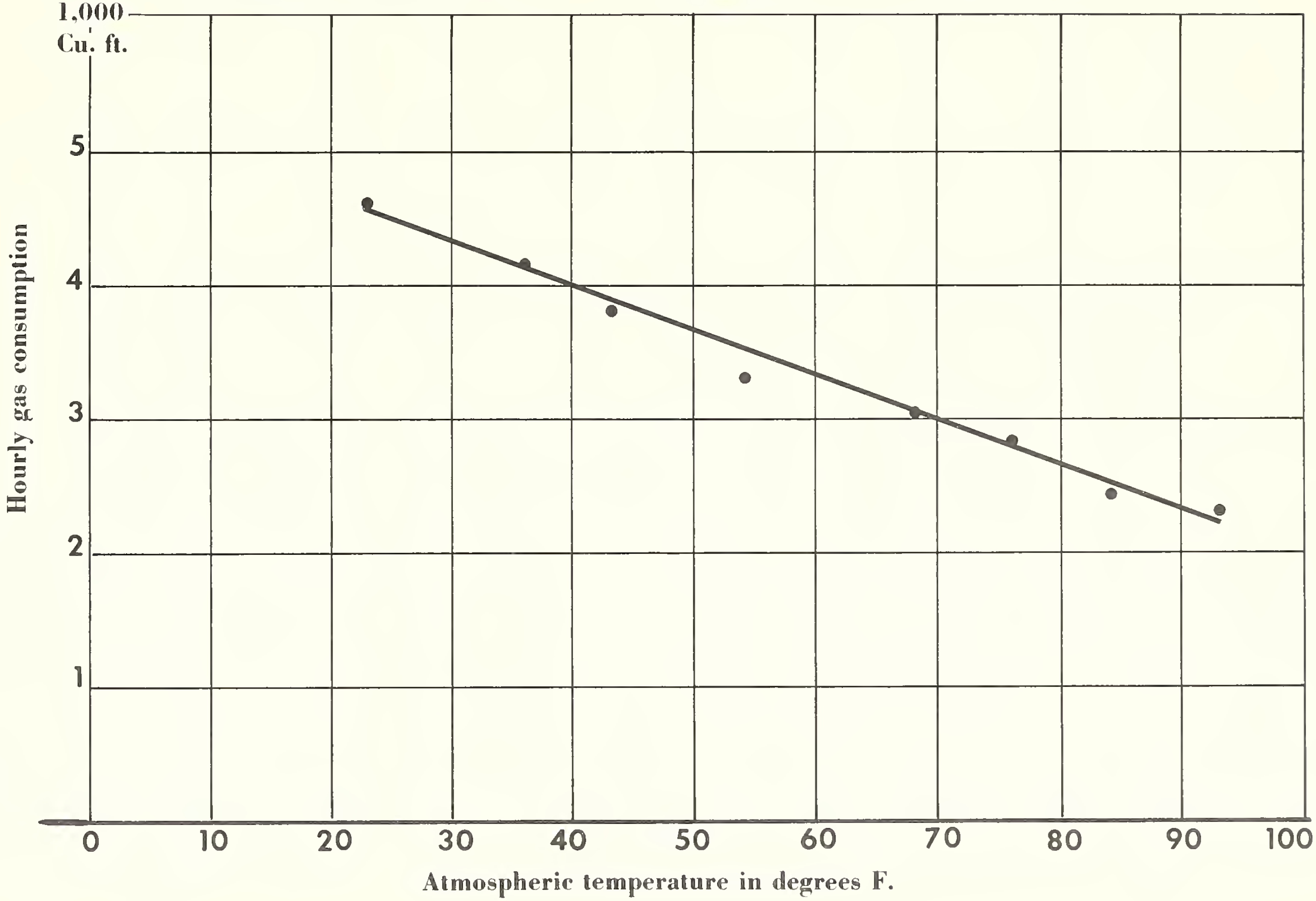
Atmospheric temperature of interval[1]	Number of degrees raised to reach 180°	Percentage of average degrees raised[2]	Fuel consumed: Amount consumed per hour	Fuel consumed: Percentage of average hourly consumption[3]	Percentage of time dryers operated at each interval
Degrees F	*Degrees F*		*1,000 cu. ft.*		
23	157	118	4,591	128	3.0
36	144	108	4,144	115	41.6
43	137	103	3,816	106	27.6
54	126	95	3,274	91	7.2
68	112	84	3,013	84	10.3
76	104	78	2,821	78	7.4
84	96	72	2,413	67	2.4
93	87	65	2,302	64	0.5

[1]Average for 10° intervals, 20.1 - 30, etc.
[2]Average necessary increase for the year was 133° F., representing an average atmospheric temperature of 47° F. during time these dryers operated.
[3]Average hourly fuel consumption for 4,012 hours operating time was 3,500 cubic feet of natural gas measured at 4 ounces under standard conditions.

Source for fuel and hours of operation: Pressure variation charts from records of fuel suppliers.

Figure 4

Hourly Rate of Fuel Consumption in Drying Grain Related to Atmospheric Temperature at Two Kansas Local Elevators With Dryers of Equal Size Operated 4,012 Hours With Air Temperatures of 180° F, August 1957-July 1958



Note: Data are shown in table 8

fuel consumption for each size dryer and on the assumption that 15 percent of the grain was dried in the summer and 85 percent in the fall. To determine the price paid for the fuel, we assumed (1) an average rate of drying per hour for each dryer for the year studied, (2) that the drying was done during the day, (3) that the drying was done straight through each month, and (4) that the price rate schedule given here was used, with sales tax added.

For example, the 500-bushel batch-type dryer dried an average of 205 bushels an hour. To calculate fuel costs, we divided total assumed bushels dried by bushels dried per hour to get the hours of dryer operation.

Annual fuel consumption was computed on the basis of hours of operation and rate of fuel consumption. For batch dryers, only the actual time the dryer was consuming fuel was used; this excluded time spent in cooling grain and in loading and unloading the dryer. Based on the proportion dried in summer and fall and the assumption that drying was done straight through during daytime operation, the fuel used was divided into billing periods and the rate schedule applied to arrive at the annual fuel cost figure.

Similar calculations were made for other dryers and for various assumed annual volumes of grain dried.

Electric Power. - Electricity used directly by the dryer plus that used by the elevator in additional elevations of grain resulting from dryer operations are included in the electric power cost item.

The number of additional elevations of grain involved may vary according to practices of individual elevators. Some operators run grain through the dryer two or more times when the original moisture content exceeds about 17 or 18 percent. When only one pass through the dryer is the practice, additional elevations usually number one or two. Most elevators in the 10 studied said one and one-half additional elevations of grain dried would be average.

The elevators did not have separate meters to measure the amount of electricity used in drying; therefore, approximate amounts were calculated for this study. Calculations were made on an hourly basis by the formula: Horsepower of motors multiplied by 0.75 multiplied by hours of operation equals kilowatt-hours used. To compute costs, hours of operation were first determined. Elevating time was based on the rated leg capacity and number of bushels elevated.

It was assumed that if leg rate were reached the motors would develop near their horsepower and it would require fully the 0.75 kw. on the inlet side of the motor to develop one horsepower. If leg rate were not reached, less current would be used per hour and more hours would be required. The current used by the dryer per bushel of grain will vary with the rate of drying. Budgeted costs were based on average drying time of the case study elevators and final moisture content as discussed previously under fuel costs.

For the budgeted figures, the rate charged for electric power used in drying operations was $0.025 a kilowatt-hour. This is based upon the assumption that drying operations are supplementary to other elevator operations; consequently, the dryer used the last part of the electric power consumed each billing period and paid at the rate applying to that portion of the total power consumed.

In the study elevators, this most frequently resulted in the rate of $0.025 a kilowatt-hour for power used by the drying operations. There were, however, eight rate schedules that applied to the 10 elevators included in the cost analysis of this study.

The following power rate schedule, with no demand charge, was selected as being the most nearly representative of the operations studied:

Quantity	Rate
First 12 kw-hr per month at	$1.00 minimum
Next 88 kw-hr per month at	0.060
Next 100 kw-hr per month at	0.045
Next 800 kw-hr per month at	0.040
Next 1000 kw-hr per month at	0.020
All in excess of 2000 kw-hrs at	0.025

Administrative. - Administrative costs for drying operations were assumed to be variable rather than fixed. If drying operations are supplementary to elevator operation, a charge for office overhead and managerial time is made to the dryer only when grain is being dried. However, if grain drying were a separate department, the costs would be considered fixed and a portion would be chargeable to drying operations whether or not any grain was dried.

None of the study elevators had made a clear and definite determination of these costs. But the operators were well aware that grain drying involved the following administrative tasks:

1. Sampling and testing grain on arrival for moisture content determination.

2. Calculating

   a. Drying charge,
   b. Shrinkage, and
   c. Handling charges on grain being returned to the farm or elsewhere for the customer's account

3. Applying these calculations to settlement for grain purchased and other purposes as needed.

4. Explaining charges to farmers before grain is dried and at settlement.

5. Supervising dryer operation and maintenance.

6. Supervising handling and special treatment of wet grain stocks.

A typical example of these costs, with drying done during the normal day's operating time of 9 hours, is:

Employees	Percent of time given to dryer	Annual wage	Hourly wage[1]	Cost to dryer per hr. of operating time
Manager	10	$5,200	$1.85	$0.18
Scale man	10	4,200	1.50	0.15
Bookkeeper	10	4,200	1.50	0.15
Asst. Bookkeeper	10	3,000	1.07	0.11
Total hourly cost to dryer when running				$0.59

[1]Based on 2,808 hours, or 52 weeks at 54 hours each.

The hours of dryer operation were applied to the hourly cost figure shown in the preceding tabulation to arrive at the total annual administrative cost incurred in the grain drying operation for the specified amounts of grain dried. Other factors such as moisture content reduction were assumed the same as specified earlier.

Effect of Seasonal Problems

At times additional drying capacity or personnel may be needed to concentrate the volume of grain to be dried within the practical drying season. The kind of grain and time of harvest would influence this. Normally fall harvests cover a longer period than summer harvests. Also fall harvested grains can wait longer to be dried because of a more extended harvest season and lower grain and atmospheric temperatures. During the year under study, some sorghum grain from the 1957 harvest was dried as late as February 1958. Very little wheat was available for drying after the end of July.

In this study, the practical drying seasons were assumed to be one month in summer and three months in the fall. It was also assumed that when it is impossible to dry all wet grain during the daytime, using a dryer around the clock by hiring additional personnel is more economical than adding dryer capacity. However, the addition of either labor or drying facilities would increase the budgeted drying costs shown in tables 4, 5, 6, and 7, even though other factors, such as moisture content and input prices, remained unchanged.

Drying around the clock, the summer drying season would be approximately 720 hours; the fall drying season, 2,160 hours. The question, then, is what is the maximum amount of grain that can be dried within these periods assuming that the elevator has facilities to receive and store this maximum quantity.

Table 9 shows the annual volumes of grain it would be practical to dry from about 16.3 to 13.0 percent moisture content, by type and size of dryer and at the drying rates given in appendix table 2. Drying would be on a 24-hour basis.

On these assumptions, costs of drying grain on a round-the-clock basis would remain about the same as shown in tables 4, 5, 6, and 7, except for labor. Labor costs would be about doubled, or about 0.54 cents a bushel for the 500-bushel batch dryer with

Table 9. - *Maximum potential annual volume of dryers by type and size, operating 24 hours a day for a practical drying season of 4 months of the year (2,880 hours)*

Type dryer	Rated capacity per hour	Grain dried per hour[1]	Annual capacity potential
		Bushels	
Batch	500	205	590,000
Continuous-flow	150	167	481,000
Continuous-flow	300	228	657,000
Continuous-flow	600	458	1,319,000

[1]Average rate of drying at Kansas local elevators, July 1957 through August 1958.

24-hour operation. For other dryers, a similar increase in labor costs would occur.

The potentials shown in table 9 range from about 53 to 146 percent of average grain receipts at the 10 case study elevators, August 1957 through July 1958, as shown in table 1. If volumes of grain to be dried exceeded these potentials, or if summer harvested grains amounted to considerably over 1/4 of total volume, an additional or larger dryer would be needed. This would change the pattern of the cost-volume relationships computed for this study.

The Farmer's Decision on Whether to Dry Grain

In deciding when and how to harvest, the farmer has several possible alternatives. He can let the grain dry naturally in the field or he can harvest it wet. If he decides to harvest it wet, he can either have it dried mechanically or he may be able to sell limited amounts wet at a discounted price. The local elevator's practices with regard to receiving wet grain, of course, have a direct bearing on this decision.

If the local elevator will not receive wet grain, then the farmer cannot harvest it wet unless he has facilities to take care of it on his own farm. On the other hand, unless enough farmers want to harvest wet grain and pay the expenses involved in drying, the elevator will have no wet grain to dry and so will have no use for a dryer.

Advantages of Earlier Harvest

Earlier harvesting offers several advantages to farmers. It frees land earlier for other purposes. Since farmers who harvest early probably will not all do so at the same time, harvesting in an area is likely to be spread over a longer period. This relieves harvesting congestion and delay.

In addition, earlier harvesting benefits the farmer by:

1. Keeping weight losses from weather causes such as shattering, flooding and lodging, and hail to a minimum. Kansas is in an area where hail damage is high. Also, considerable grain is subject to flood loss, especially in eastern Kansas. Early harvest would reduce the time grain is exposed to these weather hazards and undoubtedly would increase the quantity saved.

2. Avoiding any weight loss from excessive field drying. Grain left in the field to dry below the maximum moisture content to command the top price weighs less but does not bring any premium in price.

Closely connected with the last mentioned factor is whether the elevator operator dries grain to or below the maximum moisture content for dry grain. If he dries below the maximum moisture content and credits the farmer with the amount of dry grain by weight, this would offset the benefits of earlier harvest.

3. Minimizing weather damage of discoloration, sprouting, and lowered test weight which lower the grade and reduce the price the farmer receives for the grain.

4. Reducing losses from excessive machine shattering or ear losses in corn harvested after field drying takes place.

In 1954 the Agricultural Research Service of the U. S. Department of Agriculture *(20)*[4] estimated that harvesting losses from machine shattering amount to the following percentages of total grain production:

Cereal grains (wheat, barley, oats, rye, rice)	5 percent
Corn	8 percent
Sorghum grain	15 percent
Soybeans for beans	5 percent

The Service also stated that much of this loss could be avoided and additional grain saved by "timely harvest combined with drying of grain by mechanical ventilation."

Assuming that these estimated losses are representative of Kansas, and based on the quantities of these grains produced in Kansas, 1954-58, the weighted average of grain losses in the State from the causes listed would amount to 7.6 percent of production.

It is true that the Agricultural Research Service estimates were made in 1954 and so do not reflect increased quantities of grain that may be saved now as a result of harvesting improvements. On the other hand, losses of grain from weather hazards that would be avoided by earlier harvest are not reflected in the figures either.

Research also shows that more grain of higher quality can be saved if it is harvested before the natural grain moisture is reduced to a safe level for storage. Johnson *(11)* found that the quality of wheat was highest at 30 percent moisture content, but because of mechanical damage done to grain combined in the 20 to 30 percent range, he recommended that it not be harvested above 20 percent in moisture content.

Hurst and others *(10)* state that potential quality of soft red winter wheat in terms of test weight decreased at an average rate of one pound a bushel every 4 days from 30 percent moisture content until after the normal combine season. Scott and others *(16)* found that protein quality in hard red winter wheat, as measured by baking and physical dough properties, reached a maximum about 10 to 14 days before ripe enough to combine after which quality declined. They also found that maximum protein quality was reached at about the same time as maximum yield and test weight.

Other studies *(1, 9, 13, 19)* indicate that test weight is higher when grain is harvested before the natural moisture is reduced to a safe storage level. That is, after the wet grain is dried artifically, test weight is higher than if the grain were permitted to dry in the field.

Summarizing, net benefits to the farmer from earlier harvesting depend upon the additional grain saved, the price received for the grain, and the added costs incurred. Evidence indicates that grain harvested early will bring the farmer more money than grain dried naturally in the field.

Problems of Moisture Content

Field drying below the maximum moisture content for grain for which top price is paid decreases the number of bushels, usually without an offsetting increase in price. This reduces the farmer's grain receipts and also his cash receipts. Management of the 11 case study elevators estimated that in 1957, 80 percent of the wheat and barley,

[4]Numbers in parentheses and italics designate literature cited on pages 63 and 64.

25 percent of the oats, 11 percent of the corn, and one percent of the sorghum grain received were below 13 percent in moisture content (table 10).

It may appear that if these estimated percentages of receipts were subdry, plenty of subdry grain would be available for commingling and dryers would not be needed, especially for wheat. This would be true if the subdry grain were received at the same time as the wet grain and all receipts were of the same basic quality. But ordinarily this is not the case. Grain and atmospheric temperatures during wheat harvest do not permit high moisture grain to be held long. Also, some elevators follow the practice of not receiving wet wheat which may have caused the high percentage of receipts of subdry wheat and barley at the Kansas elevators.

The economic losses that can result from drying grain to a moisture content rated as subdry are shown for various levels of drying and for various prices of dry grain in table 11. Such losses are the same whether grain is dried naturally or artifically. For example, the table shows that if dry grain of 13 percent moisture content is selling for $1.75 a bushel, the loss on grain dried to 10 percent moisture content would be 5.83 cents a bushel (based on the number of bushels at 13 percent moisture).

During the month ending July 15, 1957, according to U. S. Department of Agriculture figures, Kansas farmers received an average price of $1.87 a bushel for wheat. Therefore, excessive drying to 10 percent moisture would have meant a loss of about 6.23 cents a dry bushel.

Selling at a Discounted Price

After the farmer has harvested wet grain, he must decide whether he should sell it at a discounted price, if he can, or have it dried artifically.

Grain marketed wet is usually discounted. The discount varies but commonly runs 1 cent a bushel below the price for dry grain for each 1/4 percent the moisture content exceeds that of dry grain. The discount is set on the basis of the relative amounts of wet and dry grain coming to the terminal market to keep them in manageable proportions and is quite independent of the price of grain.

Table 10. - *Estimated average percentage distribution of grain receipts*[1] *by moisture content ranges at 11 Kansas local elevators, 1957 crop*

Grain	Moisture group					Total
	Under 13%	13-14%	14-15%	15-16%	Over 16%	
	Percent of grain					
Wheat	80	6	8	3	3	100
Corn	11	11	65	4	9	100
Sorghum	1	38	18	28	15	100
Oats	25	7	24	32	12	100
Barley	80	8	7	4	1	100

[1]Weighted by number of bushels received.

Table 11. - *Loss[1] per dry bushel at various prices of dry grain when grain is dried excessively*

Final moisture content of the grain	Loss in weight per dry bushel	Money loss[1] per dry bushel from excessive drying to moisture content in column 1 at these prices of dry grain							
		$2.50	$2.25	$2.00	$1.75	$1.50	$1.25	$1.00	$0.75
Percent		*Cents per bushel*							
[2]13									
12	1.14	2.85	2.56	2.28	2.00	1.71	1.42	1.14	0.86
11	2.25	5.62	5.06	4.50	3.94	3.38	2.81	2.25	1.69
10	3.33	8.32	7.49	6.66	5.83	5.00	4.16	3.33	2.50
9	4.40	11.00	9.90	8.80	7.70	6.60	5.50	4.40	3.30
8	5.43	13.58	12.22	10.86	9.50	8.14	6.79	5.43	4.07
[2]15.5									
14.5	1.17	2.92	2.63	2.34	2.05	1.76	1.46	1.17	0.88
13.5	2.31	5.78	5.20	4.62	4.04	3.46	2.89	2.31	1.73
12.5	3.43	8.58	7.72	6.86	6.00	5.14	4.29	3.43	2.57
11.5	4.52	11.30	10.17	9.04	7.91	6.78	5.65	4.52	3.39
10.5	5.59	13.98	12.58	11.18	9.78	8.38	6.99	5.59	4.19
9.5	6.63	16.58	14.92	13.26	11.60	9.94	8.29	6.63	4.97
8.5	7.65	19.12	17.21	15.30	13.39	11.48	9.56	7.65	5.74

[1]Loss applies to any kind of grain and is not dependent on pounds of dry grain per bushel.
[2]The moisture content of grain that commands top prices as dry grain sometimes varies with the kind of grain or by locality. These data apply to only two situations; grain considered dry at 13 or 15.5 percent moisture content.

Persons in the grain trade who were interviewed in connection with this report thought that discounts were larger when the price was depressed. In a study on drying wheat and corn on North Carolina farms, Martin and Toussaint *(14)* say "The magnitude of these deductions for high moisture corn and wheat are not related to the market price of grain." Discounts in effect in Kansas during this study showed that sorghum grain was often discounted as much as wheat, a higher priced grain.

If the farmer can either dry wet grain or sell it at a discounted price, he should weigh carefully the drying costs (including shrinkage costs) against the discount and choose the alternative that will assure him more money. If the grain would be eligible for Government loan if it were dried and the loan rate exceeds the market price for dry grain, this would be an added incentive for the farmer to dry his wet grain.

Drying Charges and Shrinkage

In 1957-58, charges for drying 607,423 bushels[5] of grain at 11 Kansas local elevators from an average of about 16.3 to 13 percent moisture content[6] averaged 5.4 cents a bushel. Table 12 and figure 5 show this charge, plus shrinkage, as total drying costs to the farmer. Drying costs are compared with the discount for that amount of moisture. Thus, the economic gain per bushel to be derived from drying grain from 16.3 to 13 percent moisture, rather

[5]Volume of grain covered by daily drying reports.
[6]Charges were based on drying to 13 percent; the grain was actually dried to an average of 12.6 percent moisture content.

than selling it wet at a discounted price, is shown at various prices for dry grain. For example, it paid the farmer to dry grain of this moisture content when the discount per bushel was 1 cent a 1/4 percent of moisture above 13, as long as the price of dry grain was below $1.97 a bushel. At prices above $1.97 a bushel, it was more advantageous to take the discount than to dry the grain.

Appendix table 4 and figure 6 show the per bushel discounts at differing rates and the shrinkage costs at various prices of dry grain for grain of various moisture content discounted and dried to 13 percent moisture. If the moisture content of the wet grain, the discount rate, and price of dry grain are known, you can refer to the table or chart and determine how much money is available to pay direct drying costs.

For example, if the moisture content is 18 percent, and the discount is 1 cent for each 1/4 percent moisture exceeds 13 percent (moisture content of dry grain), and the price of dry grain is $1.00 a bushel, the discount per bushel is 20 cents and shrinkage cost per bushel is 6.25 cents. Discount exceeds shrinkage costs in this example by 13.75 cents per bushel and that is the amount available to pay direct drying costs. Any amount the 13.75 cents exceeds drying costs or charges is economic incentive to dry grain.

Storing Under Government Loan

The possible economic advantages to the farmer in being able to store his grain under Government loan were not included in the preceeding example.

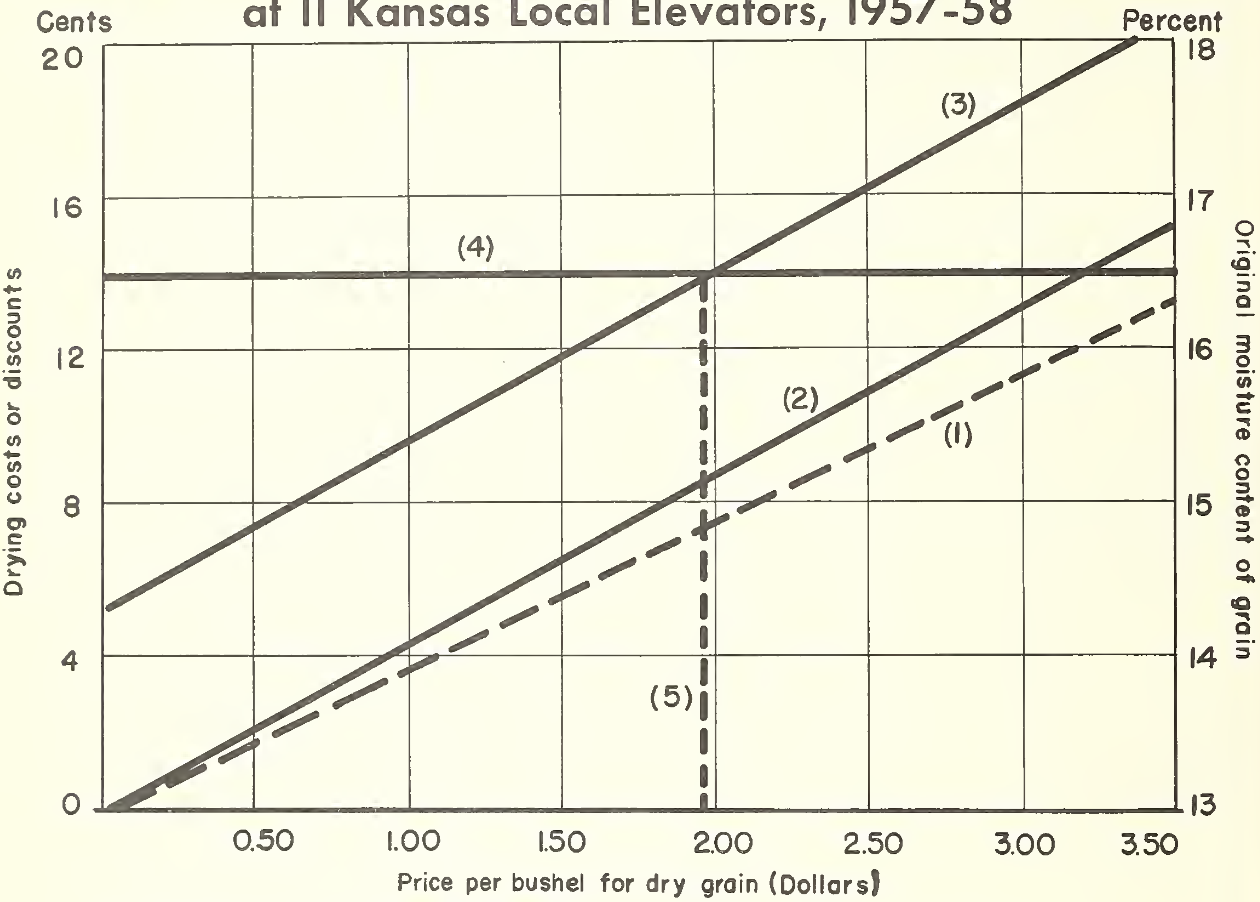
Table 12. - *Economic gains or losses to farmers in drying grains from 16.32 percent*[1] *to 13 percent moisture content at 11 Kansas local elevators at various prices of dry grain, 1957-58*

Price of dry grain per bushel	Discount per bushel for 16.32% moisture grain	Drying charges per bushel			Economic gain or loss per bushel from drying grain
		Shrinkage[2]	Direct drying charges[3]	Total	
Dollars		*Cents*			
0.50	14.00	2.18	5.40	7.58	6.42
0.75	14.00	3.27	5.40	8.67	5.33
1.00	14.00	4.36	5.40	9.76	4.24
1.25	14.00	5.45	5.40	10.85	3.15
1.50	14.00	6.54	5.40	11.94	2.06
1.75	14.00	7.63	5.40	13.03	0.97
1.97	14.00	8.60	5.40	14.00	0.00
2.00	14.00	8.72	5.40	14.12	-0.12
2.25	14.00	9.81	5.40	15.21	-1.21
2.50	14.00	10.90	5.40	16.30	-2.30
2.75	14.00	11.99	5.40	17.39	-3.39
3.00	14.00	13.08	5.40	18.48	-4.48

[1] Average original moisture content of grain dried.
[2] Based on water loss plus 0.5 percent hidden loss of the original weight.
[3] Average charge for drying grain of 16.32 percent moisture content at elevators studied.

Figure 5

The Farmer's Total Cost per Bushel of Drying Grain Related to the Price of Dry Grain and Moisture Discounts at 11 Kansas Local Elevators, 1957-58 [1]



(1) Shrinkage cost of moisture loss.
(2) Shrinkage cost of moisture loss plus 0.5 percent hidden loss of weight.
(3) Farmer's total per bushel costs of drying grain - total shrinkage loss plus 5.40 cents average drying charge.
(4) Discount per bushel for moisture of grain testing 16.32 percent moisture at a schedule of one cent per quarter percent above 13 percent.
(5) Price of dry grain when the farmer's cost to dry would have been equal to the moisture discount.

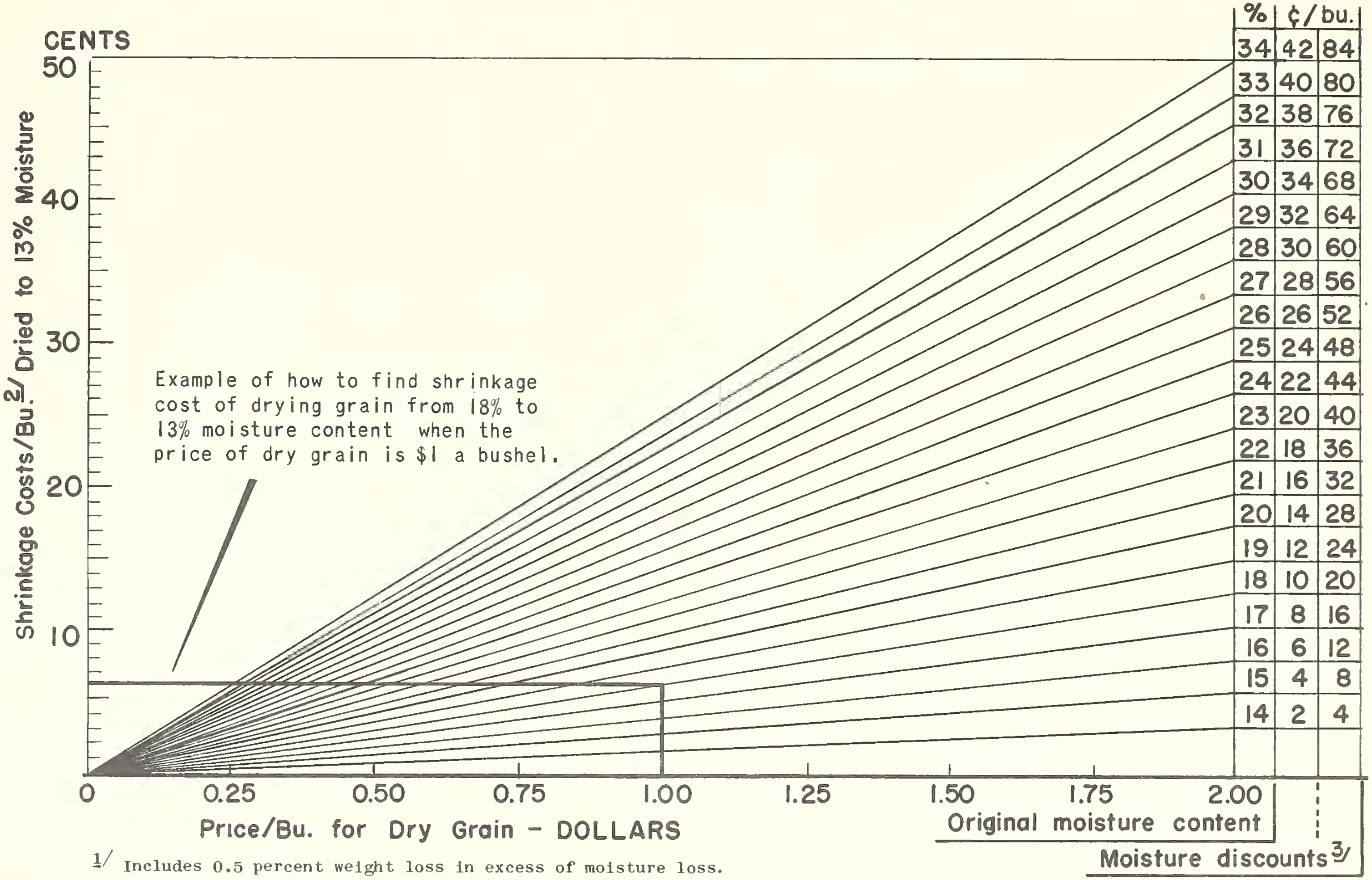
[1] This chart is based on data shown in table 12.

Appendix table 5 shows the daily ranges in the cash price for wheat at Kansas City, Mo., during the heavy wheat marketing season of 1958. These cash prices compare with the net loan rate at Kansas City of $2.02 for the same class and grade of wheat stored between June 30 and July 21, 1958.

The maximum difference between the loan rate and cash price occurred on July 1 and amounted to 33 cents a bushel. On that date, then, there was a maximum added incentive of 33 cents a bushel to dry any wheat that would be made eligible for Government loan by drying. On other dates, this incentive was less.

Figure 6

Shrinkage Costs[1/] of Drying Grain to 13 Percent Moisture Content Related to the Price of Dry Grain and to Commerical Discounts for Moisture Above 13 Percent



1/ Includes 0.5 percent weight loss in excess of moisture loss.

2/ Cost per original bushel.

3/ One-half and one cent per one-fourth percent of moisture above 13 percent.

These prices and loan rate are basis Kansas City. However, the difference between cash price and loan rate at Kansas local points would be about the same as at Kansas City.

The Elevator's Decision on Buying a Grain Dryer

It is not always easy for a local elevator management to decide whether investment in a grain dryer is economically advisable.

Managers of the 11 elevators studied were asked why they had decided to install grain dryers and also to mention any disadvantages to owning a grain dryer. Perhaps this summary of their replies will be helpful to other elevator operators now considering the problem.

The reasons managers gave for installing grain dryers were:

1. Necessary to dry wet wheat for storage.

2. To increase business.

3. Previous experience with wet grain undesirable.

4. Terminals receive only limited amounts of wet grain.

5. Corn-picker sheller operates better on corn of too high moisture content for safe storage.

6. At times early harvest saves grain from loss caused by river overflow.

7. Competition for grain by other elevators that had dryers.

8. Farmers had trouble with farm-stored grain getting musty.

9. Irrigated grains tend to be high in moisture because of high plant moisture being squeezed into the grain mass in harvesting.

Managers also were asked whether the expressed desires of patrons or customers were a factor in their decisions to install grain dryers. Five said "yes," four said "no," and two had had a change in managers since the dryer was installed and so could not answer definitely.

Before coming to a decision on buying a dryer, local elevator management should also consider possible disadvantages that might result from adding this service. Managers of the elevators studied mentioned these disadvantages to owning a dryer.

1. Drying grain may necessitate hiring extra help which cannot be fully utilized.

2. Drying grain may cause a longer money tie up in grain inventories, thus involving more risk.

3. Receiving wet grain and operating a dryer may slow down other receiving operations thus causing dissatisfaction among farmers. Some dry grain may be lost as a consequence.

4. If capital is limited, investment in a dryer may prevent investment in other more profitable facilities.

5. Drying causes additional bookkeeping and management problems.

This report makes no effort to provide a general answer to the question of the advisability of installing a grain dryer but, rather, enumerates and discusses factors of concern. Each elevator manager must consider and evaluate these factors in the light of his own situation.

Alternative Methods of Handling Wet Grain

An elevator can, of course, refuse to receive wet grain. But if the decision is made to accept grain with moisture content too high for safe storage, the next problem is to find a method of disposition.

There are several possible methods of handling wet grain. It can be dried, limited amounts can be shipped wet, or it can be blended with subdry grain so that the average moisture content is not above the maximum for dry grain. Each of these methods has advantages and disadvantages.

Blending to Avoid Drying

When wet grain can be blended satisfactorily with subdry grain, this offers more economic advantage than any other method. There is very little weight loss and the total amount of grain sold will tend to be maximized without any discount in prices for moisture. The added cost of blending may be greater than the added cost of shipping wet grain but less than the cost of drying it mechanically.

Disadvantages and limitations to this type of blending are:

1. Adequate quantities of subdry grain of similar basic quality and value are not always available for blending.

2. There is less variation in moisture content in fall harvested grain than in wheat and other summer harvested grains. Fall-harvested grains are more apt to be all wet or all dry.

3. Managers of the elevators studied said farmers do not like to be charged for drying when the wet grain ultimately is disposed of by blending.

4. Unless blending is done with care, the grade of the grain can be lowered generally and money lost. If wet and subdry grain are not blended in proper amounts to lower the average moisture to the desired level for dry grain, it is possible for an elevator to end up with more wet grain, but of lower moisture content, than it received wet.

Blending Before Drying

The alternative method of blending extremely wet grain with grain not so wet and drying the blend has some advantages over drying without blending. It tends to keep the grain moisture content low enough to avoid excessive caking and permits easy flow of the grain, thus keeping the wet grain from clogging up the machinery. Also, it affords opportunity to keep the average moisture content of grain to be dried more uniform and requires less adjusting in the drying rate to turn out uniformly dried grain of the desired moisture content.

Moreover, the physical aspects of drying are such that if too much moisture is removed at one drying, the rate is slower and more expensive and there is more danger of overheating and damaging the grain. On the other hand, this study indicated that if too little moisture is removed at one pass through the dryer, the drying rate in terms of moisture removed is slowed down and economic efficiency lowered. Operators of some of the dryers studied believed that around 5 percentage points of

moisture removed at one pass through the dryer was best for efficient and safe drying operations.

Shipping Wet Grain

Local elevators in Kansas cannot ship wet grain in quantity because most terminal elevators serving the State will take wet grain only on condition that they can dispose of it themselves. If they have subdry grain of similar quality, they blend to make the average moisture acceptable. If the terminal cannot dispose of the wet grain, the local is responsible for it. There have been cases where a terminal actually returned wet grain to a local elevator at the local's expense for transportation.

Most of the locals studied did not knowingly ship wet grain. Any grain inadvertently shipped wet and accepted by the terminal was discounted an amount which usually made it uneconomical for a local with a dryer to ship that way.

When it is necessary to decide whether to dry grain or ship it wet, an additional factor to consider is the saving in freight costs from shipping the dry and lighter weight grain *(17)*.

Importance of Available Grain Volume

The discussion of cost-volume relationships earlier in this study showed why expected volume of grain to be dried is important to the decision of whether to install a grain dryer. As pointed out, volume dried has a direct bearing on ownership or fixed costs per bushel. Moreover, once a dryer is installed, the fixed costs are committed; current or variable costs are incurred only when grain is dried.

Tables 4, 5, 6, and 7 show the relationship between per bushel fixed costs and annual volume of grain dried for four sizes of dryers. For example, if a 600-bushel-per-hour continuous-flow unit dried only 10,000 bushels of grain annually, fixed costs alone would amount to over 27 cents a bushel. With a volume of 100,000 bushels annually, these fixed costs would drop to less than 3 cents a bushel.

Some of the elevators selected for this study found it necessary to restrict wet grain deliveries at times during 1957-58. However, for purposes of this discussion, it is assumed that it is the policy of elevators with dryers not to restrict wet grain deliveries. Under this condition, the annual volume of wet grain that a local elevator will have available to dry depends on such factors as:

1. Kinds and volumes of grain produced and marketed locally.

2. Farm storage available and practices of local farmers, including extent to which farm dryers are used.

3. Harvesting practices and kind of machinery used.

4. Number, size, location, and kind of service offered by competitive elevators, including drying services.

5. Practices of the grain trade in receiving and handling wet grain, including charges for drying.

6. Whether there is general acceptance of artifically dried grain by grain processors and other users.

The volume of grain produced and sold in Kansas, 1950-58, is shown, by kinds, in table 13. Total volumes

Table 13. - *Production and off farm sales of grain in Kansas, 1950-58*

Crop year produced sold	Wheat	Corn	Sorghum grain	Oats	Barley	Rye	Soybeans	Total
				1,000 bushels				
1950								
Produced	178,060	89,495	44,689	20,160	3,683	420	7,146	343,653
Sold	163,352	32,479	26,813	3,629	700	233	6,845	234,051
1951								
Produced	126,113	58,296	57,310	14,346	1,547	285	5,814	263,711
Sold	113,152	18,371	40,117	2,869	294	167	5,456	180,426
1952								
Produced	307,629	59,840	18,536	18,142	1,333	462	7,360	413,302
Sold	294,358	17,427	9,453	2,903	213	329	6,939	331,622
1953								
Produced	144,662	50,869	30,640	22,833	1,568	361	3,968	254,901
Sold	133,806	16,001	18,078	5,023	455	255	3,694	177,312
1954								
Produced	176,208	39,558	47,894	36,238	9,868	935	2,448	313,149
Sold	166,848	13,658	31,610	7,972	3,355	577	2,247	226,267
1955								
Produced	128,385	34,104	33,246	30,882	12,728	690	3,350	243,385
Sold	119,739	11,221	20,945	7,103	3,818	397	3,121	166,344
1956								
Produced	143,282	32,067	24,390	23,177	10,404	759	3,018	237,097
Sold	136,758	9,911	14,634	5,331	3,433	383	2,889	173,339
1957								
Produced	100,111	44,283	129,129	34,190	15,136	2,272	2,461	327,582
Sold	91,479	16,643	95,555	7,864	5,600	1,268	2,261	220,670
1958								
Produced	296,548	73,122	128,964	13,416	18,009	2,414	9,262	541,735
Sold	287,141	30,603	83,827	2,549	7,204	1,248	8,941	421,513

Source: Field and Seed Crops, Agricultural Marketing Service, Crop Reporting Board, U. S. Department of Agriculture.

produced and sold annually in the same years and percentages of total production sold are given in appendix table 6. In recent years there has been a large increase in production and sale of sorghum grain. Since fall-harvested grains are more likely to be harvested wet than those harvested in summer, this increased production of sorghum grain is clearly reflected in total volume of grain dried. In any given year, the weather during harvest has a definite relationship to the amount of grain harvested wet.

Table 14 shows the total quantities of grain received and dried during the period 1953-57 at six Kansas elevators that had dryers throughout the period. These elevators were located mostly in the western and central parts of the State. Figure 1 and appendix table 7 show the percentages of the various grain receipts dried at these six elevators, 1953-57.

How much of the increase in volume dried is due to trends toward earlier harvest and how much to weather factors

Table 14. - *Receipts of grain and estimated[1] amounts dried at six[2] Kansas local elevators, 1953-57*

Grain receipts and volume dried	Crop year					
	1953	1954	1955	1956	1957	Average
			1,000 Bushels			
Wheat:						
Receipts	2,239	1,895	1,244	1,574	535	1,497
Dried	17	2	5	37	13	15
Corn:						
Receipts	94	70	33	96	322	123
Dried	1	2	1	25	45	15
Oats:						
Receipts	31	47	80	60	24	48
Dried	0	0	0	0	0	0
Barley:						
Receipts	24	31	53	54	24	37
Dried	0	0	1	5	1	1
Sorghum grain:						
Receipts	312	462	489	438	2,458	831
Dried	38	39	22	32	2,055	437
Totals:						
Receipts[3]	2,701	2,507	1,900	2,222	3,363	2,538
Dried	56	43	29	99	2,114	468
Per elevator	9	7	5	16	352	78

[1]Estimated by elevator management.
[2]Of the 11 elevators studied, only six had dryers in 1953.
[3]Includes small quantities of other grains, none of which were dried.

cannot be accurately determined. During the first 4 years of the period, however, smaller crops and drier than normal weather probably resulted in less than normal need for artificial drying (appendix tables 6 and 8).

More humid conditions in 1957 (appendix table 9) was a possible factor in increasing the amount of grain dried that year.

As indicated previously, a trend toward earlier harvest is in progress. This is particularly noticeable in areas increasing their use of the picker-sheller and corn combine in harvesting operations. No attempt was made in this study to measure the effects or predict the extent of such trends. However, it appears safe to say that the volume of grain available to dry in Kansas will increase in the immediate future as a result of changes in harvesting practices.

General Benefits to the Elevator and Community

Local elevators should not overlook the effect a dryer may have on their total business volume and on community well-being.

Generally speaking, an organization offering a new needed service stands to increase its volume of other business. Farmers tend to patronize an elevator that meets several of their needs in preference to one that offers only limited services. This is especially true when the services are as closely allied as grain drying and other grain marketing services.

As mentioned earlier in this report, several studies have shown that harvesting grain before it is dry enough to store safely keeps harvesting losses to a minimum and saves the maximum volume of grain of highest grade and quality. This offers an opportunity for an economic gain.

Hall *(6)* has estimated that 55 percent of grain losses could be avoided by earlier harvest. Hurlbut *(8)* says, "A normal machine loss of about 4 percent can be expected at the earliest time that corn is safe for cribbing, or when kernal moisture content is about 20 percent. As corn dries beyond this point the normal field loss increases about 3 percent per week for a period of about 4 weeks, or until the cobs become dry."

Johnson and Hurst *(12)*, studying cutter bar and shatter loss in combining wheat, found that these losses increase with a delay in harvest date. For wheat producing about 42 bushels an acre, these losses reached a total of over three bushels by July 20.

The following example illustrates the financial benefits a Kansas community might possibly derive from a successful grain drying operation.

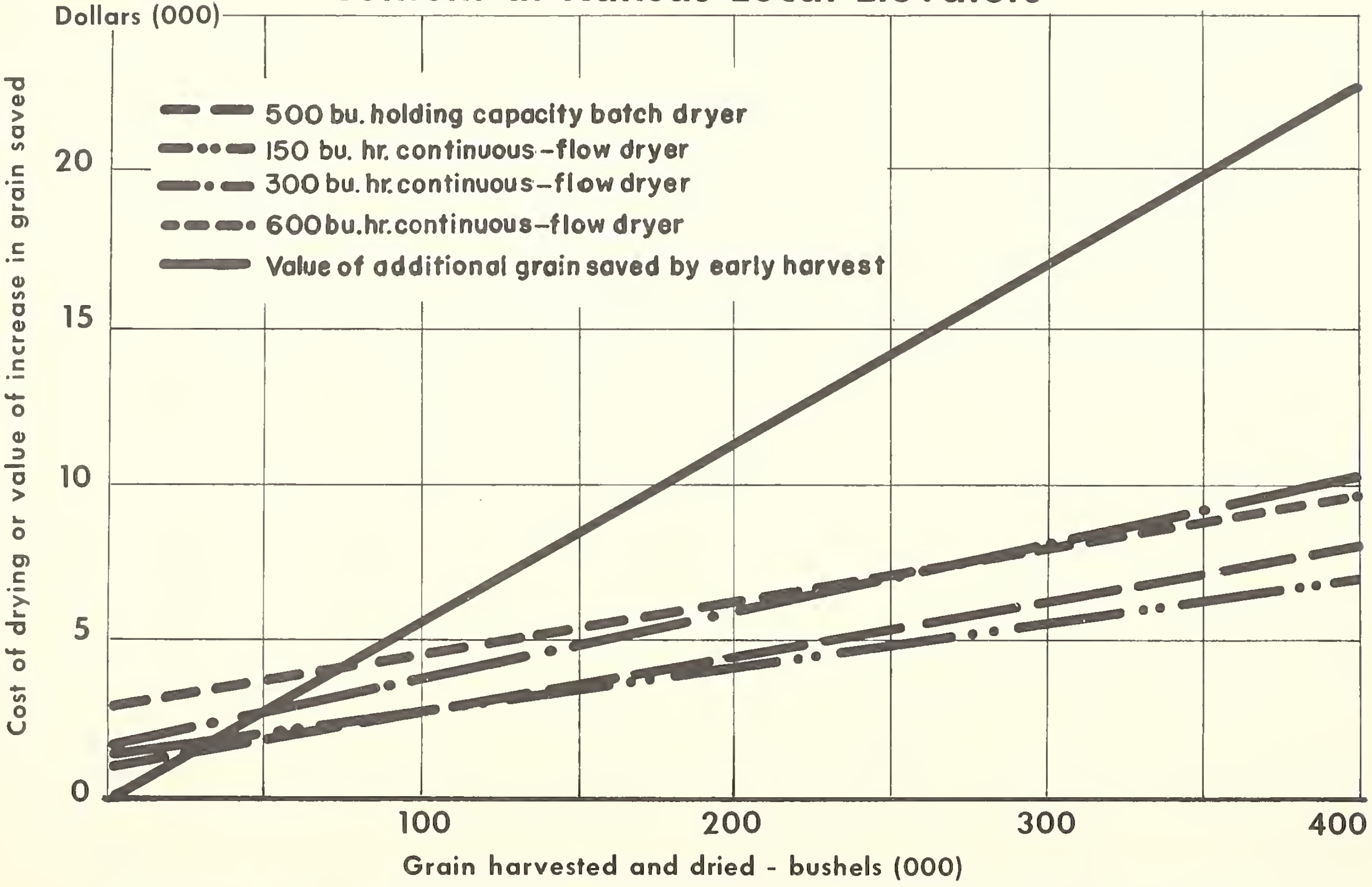
If 92.4 bushels of grain are now saved from every 100 bushels produced in Kansas, 7.6 bushels from each 100 are lost.

If this loss could be reduced by 55 percent, an additional 4.2 bushels would be saved. Total bushels saved would then be 96.6 out of each 100 produced.

At $1.32 a bushel (1960 support price weighted by production 1954-58), the additional 4.2 bushels saved would be worth $5.54. Figured on the basis of the 96.6 bushels then saved, this would be an increase of 5.73 cents a bushel or $573 for every 10,000 bushels.

Figure 7

Value of Additional Grain Saved by Early Harvest[1] and Estimated Cost[2] of Drying All the Grain From 20 to 13 Percent Moisture Content at Kansas Local Elevators



1/ Based on estimate that 4.2 additional bushels of grain could be saved by early harvest valued at the average price of $1.32 per bushel (1960 support price weighted by production 1954-58 in table 13.)

2/ Costs computed from tables 4, 5, 6, 7 with an increase in variable costs proportionate to the additional moisture removed over that shown in appendix table 2.

Figure 7 is based on the general assumption of the preceding example. It shows the relationship between increased value of grain receipts resulting from additional bushels saved, and the cost of drying all grain harvested for four different dryers. In the figure, where the solid line is above a broken cost line, it would be profitable to harvest early and dry the entire crop when using that particular size and type dryer.

Saving additional grain would mean an increase in total grain supplies. Admittedly, this might depress prices and thus harvesting and marketing costs would take a larger percentage of receipts. However, improvement in quality as a result of drying would tend to bring a better price for the grain. The net effect on the community would probably be beneficial, especially when the added income from increased labor requirements is considered.

Both the example given and figure 7 are based upon an ideal situation with all factors operating favorably. They also assume that no additional drying capacity would be required to handle the concentrated harvest. There is no intention of implying that every local elevator installing a grain dryer would record a saving like this every year. In actual practice, the benefits to be derived from drying grain are dependent upon many factors, any or all of which can vary in any given year.

In the long run, however, if grain drying brings an improvement in marketing procedures, benefits to the elevator, to the farmer, and to the community will follow.

Facilities for Drying

If a local elevator decides that the advantages of having a grain dryer are sufficient to warrant its purchase, the next step is a study of the types of dryers available. Serious thought must be given not only to cost but also to the installation of the new equipment in relation to the existing plant layout, to methods of receiving and handling wet grain, and to possible interference with other elevator operations.

In this section, types of dryers will be discussed first; then problems of drying facilities and layout.

Types of Dryers

Two general types of heated-air grain dryers are in use in Kansas -- batch and continuous-flow. Of the case study elevators, eight had continuous-flow; three had batch dryers.

In a continuous-flow dryer, the grain moves through continuously. If the original moisture content of the grain varies, the final moisture content also will vary, unless the final moisture is tested frequently and the rate of the grain flow adjusted accordingly. As long as the wet bin has grain, little attention is required to keep these dryers operating. Usually they are equipped with automatic controls which stop the machinery and sound an alarm if anything goes wrong.

With the batch type, the dryer is filled with grain, a batch is dried and cooled, and the dryer is emptied. After a batch is dried and cooled, immediate attention must be given to unloading and

reloading the dryer. Otherwise drying time will be wasted. One problem mentioned in connection with using the batch dryer is that grain tends to over-dry where the drying air enters and underdry where the air leaves the grain mass.

In deciding the type and size dryer to purchase, original cost is an important consideration. However, original cost has meaning only in its relationship to the expected length of life of the dryer and the annual volume of grain to be dried. If the volume to dry is relatively low, total per bushel direct costs of drying will be influenced greatly by depreciation costs. As the volume dried increases, depreciation exerts less influence on total per-bushel costs. Therefore, from the standpoint of direct costs, annual volumes to dry are of major importance in deciding what size dryer to install.

Installations and Layout

The general drying installation and layout should be planned for convenient and efficient operation.

A dryer will operate more uniformly during winter months and possibly use less fuel if it is located on the south side of the elevator and is protected from cold north winds. Compliance with fire safety requirements, such as those governing distance from the elevator, will keep fire insurance rates on the dryer to a minimum. This will also minimize increases in fire insurance rates on the elevator and grain stocks resulting from installation of the dryer.

Other important considerations include the number and size of bins that are accessible to the dryer for both wet and dry grain, and how much the dryer will tie up other facilities, thus affecting general elevator operations.

The number, size, and accessibility of bins will have a direct bearing on the convenience of custom drying grain to return to the farm. Many dryer installations at Kansas local elevators depended on the existing dump pits and elevator leg to unload the dryer or the dry grain bin. Where there is only one leg to the elevator or where there are two legs and more than one kind of grain is being received simultaneously, this slows operations. Farmers who want to dump grain and get back to harvest operations are delayed.

It is to the elevator's advantage to expedite service to the farmer during the harvest season. The dryer installation should be planned to meet future as well as present needs.

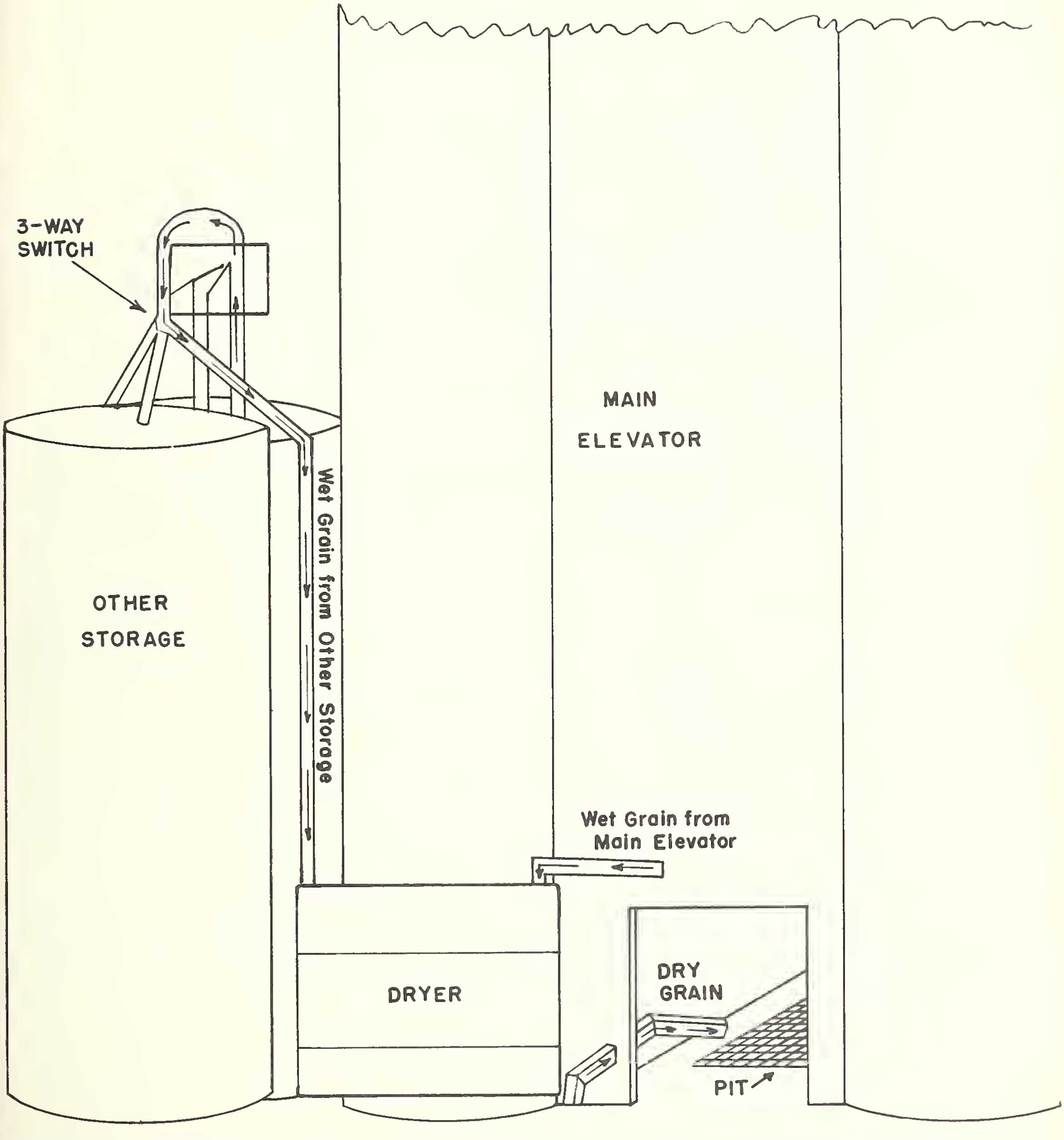
Installations at Four Kansas Elevators

Probably no two dryer installations in Kansas are precisely the same in detail of arrangement, layout, and general access to the main elevator facility and operation. However, the differences that are important to the problem of accessibility to the main elevator facility can be shown by a discussion of four dryer installations. General drawings of these are shown in figures 8, 9, 10, and 11. Grain movements are described, and some good and some poor features of each installation are pointed out.

Batch Type Dryer. - The dryer in figure 8 is a batch type. It is located in the open on a concrete slab about 4 feet from the main elevator and is a permanent installation. This general layout is not unique to a batch dryer. The same layout could be used for a continuous-flow dryer but would result in a serious disadvantage of completely tying up one pit while drying was in progress. Most batch-type dryers are

Figure 8

Type of Installation Used for Batch Grain Dryers at Kansas Elevators, 1957-58



Note: Most batch dryers were attached to only one grain receiving and handling facility. This dryer was attached to two such facilities.

attached to the main elevator only; whereas this one is attached to the main elevator and to a small metal elevator used for receiving corn.

Wet grain moves into the dryer as follows:

1. From outside leg that is attached to the metal elevator used for corn into the top of the dryer by gravity flow pipe and leveled by dryer grain levelling auger, or

2. From an overhead bind of the main elevator by gravity into an augering conveyor into the top of the dryer and leveled by dryer grain-levelling auger.

Dried grain moves from the dryer as follows:

1. From dryer by auger into main elevator dump pit.

2. From elevator pit by elevator leg into storage facilities.

One good feature of this installation is that accessibility to the dryer from either elevator makes it easy to dry two kinds of grain alternately. Another advantage is that it is possible to blend dried grain with other grain immediately, as the grain is unloaded into the elevator pit from the dryer.

A poor feature of this installation is that grain moving into the dryer from the all-metal elevator ties up that elevator's leg. Likewise, when unloading the dryer, it ties up one dump pit.

Small Continuous-flow Dryer. - The dryer in figure 9 is a small continuous-flow type. This type installation also could be used for a batch type dryer. However, this study showed that batch dryers in Kansas usually were not installed with legs for dried grain.

The small continuous-flow dryer operates this way:

1. A wet grain bin is formed by putting a sloping false bottom midway up in a bin adjacent to the dryer. Grain is elevated from the dump pit of the elevator, either from other bins or as received, into the wet grain bin.

2. Grain feeds by gravity out of the wet bin into a pipe attached to the bin at the lowest point. The grain then moves by gravity into the top of the dryer.

Dry grain moves from the dryer as follows:

1. It is delivered into conveyors and augered into the dryer leg by means of a grain metering mechanism, driven by a multiple speed motor which helps to adjust the rate of flow.

2. The dryer leg elevates the grain into the dry bin, which is the bottom half of the original bin divided to handle the wet grain.

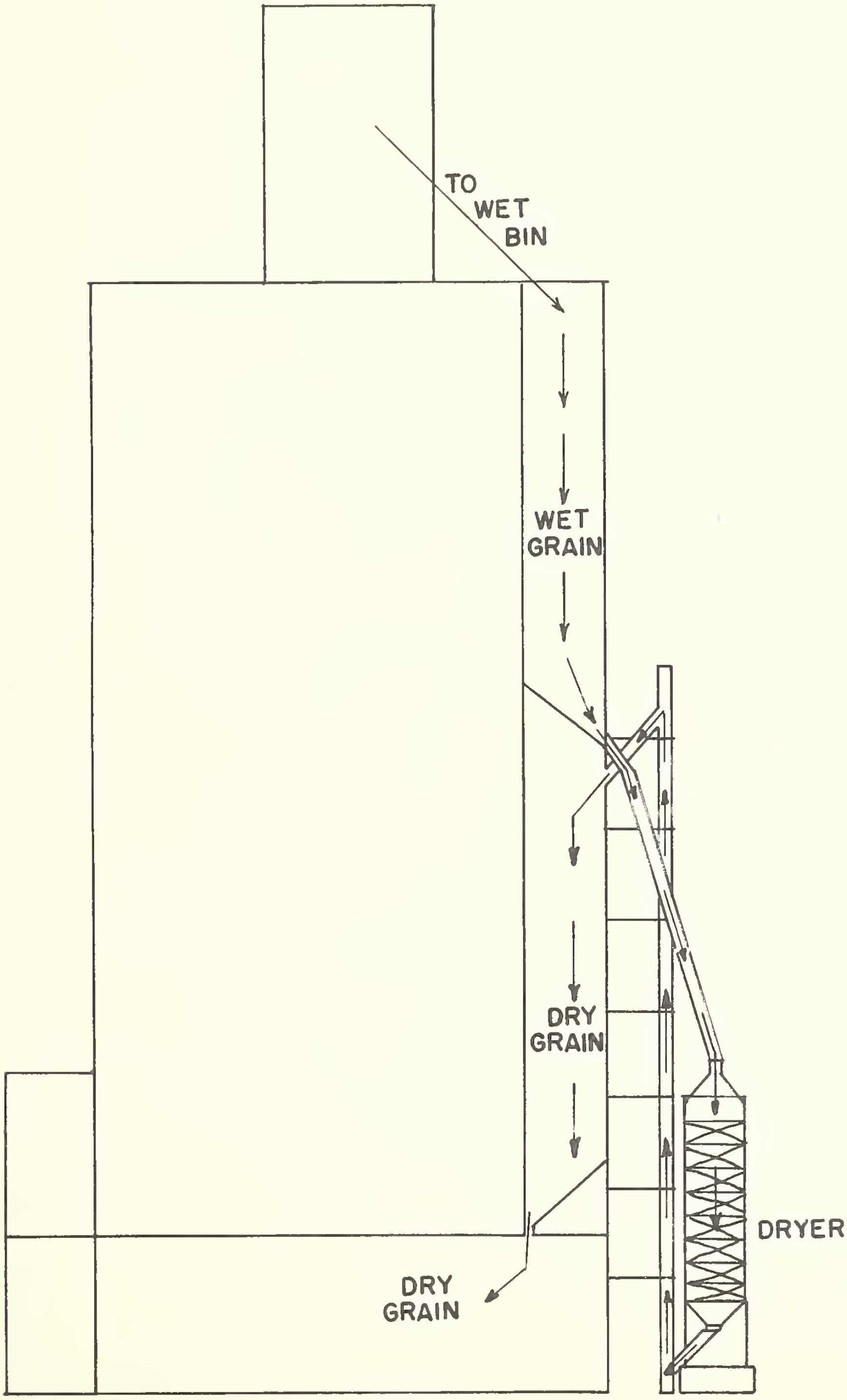
3. When the dry grain bin is full, it must be emptied. Dry grain moves through the pit and elevating machinery to other bins throughout the elevator.

An advantage of this type installation is that drying operations involve regular grain handling facilities only when the dry grain bin must be emptied or the wet bin filled.

On the other hand, this type installation offers limited access from bins to dryer. If there is much wet grain waiting to be dried, it must be stored in bins that have access to the dryer only by tying up the elevator pit and

Figure 9

Type of Installation Commonly Used for Small Continuous-Flow Grain Dryers at Kansas Elevators, 1957-58



leg. Also, it limits direct access to bin space from the dryer and ties up the elevator pit and leg to clear space for dry grain.

Medium Continuous-Flow Dryer. - Figure 10 shows a plan of a medium-size continuous-flow dryer installation that employs two dryer legs, one for loading the dryer with wet grain and one for unloading the dryer or moving the dried grain into the dry grain bin. Except for the wet grain leg, which eliminates the necessity of an overhead bin for wet grain, this layout and the one in figure 9 are about the same. Therefore, unless this type installation has conveying equipment to move grain from more than one wet bin or to more than one dry bin, the good and poor features are about the same as described for figure 9.

The only difference in grain flow is that in this layout wet grain is fed by gravity into the dryer leg, elevated and dropped by gravity into the dryer; whereas, in figure 9 the grain is fed by gravity directly from the overhead wet bin into the dryer.

Large Continuous-Flow Dryer. - The most elaborate dryer installation found at Kansas local elevators in 1957-58 is illustrated in figure 11. Used for large size continuous-flow dryers, this type installation results in the least interference with other elevator operations by the dryer. Essentially, it is the same as the layout in figure 10, but extended to make more of the elevator bin space easily accessible to the dryer. It is directly accessible to two full-sized wet grain bins. Dried grain can be moved directly to a number of bins by means of the dryer leg and overhead conveyors.

Wet grain moves into the dryer as follows:

1. From the receiving pit, it is elevated into one of the wet grain bins.

2. From these bins, it moves by gravity into the wet grain dryer leg.

3. The wet grain is elevated and dropped by gravity into the dryer. An excess returns through an overflow pipe to the dryer's wet grain pit.

Dry grain moves from the dryer as follows:

1. It is metered out the bottom of the dryer by a variable speed-metering device and augered to dry leg of dryer. This is one way of adjusting the drying rate or bushels dried per hour.

2. The dried grain is elevated to the top of the elevator and (a) discharged directly into a spout to the dry grain bin, or (b) discharged into an overhead conveyor which moves it to one of four other bins.

With this type installation, the dryer can be operated for a much longer period without interrupting or interfering with other elevator operations. This is an advantage.

Compared to the other installations, this type has no bad features. However, a large volume of drying business is needed to justify its expense.

These four layouts, with changes in some minor details, are typical of dryer installations in Kansas local elevators.

Figure 10

Type of Dryer Installation Commonly Used for Medium-Size Continuous-Flow Grain Dryers at Kansas Elevators, 1957-58

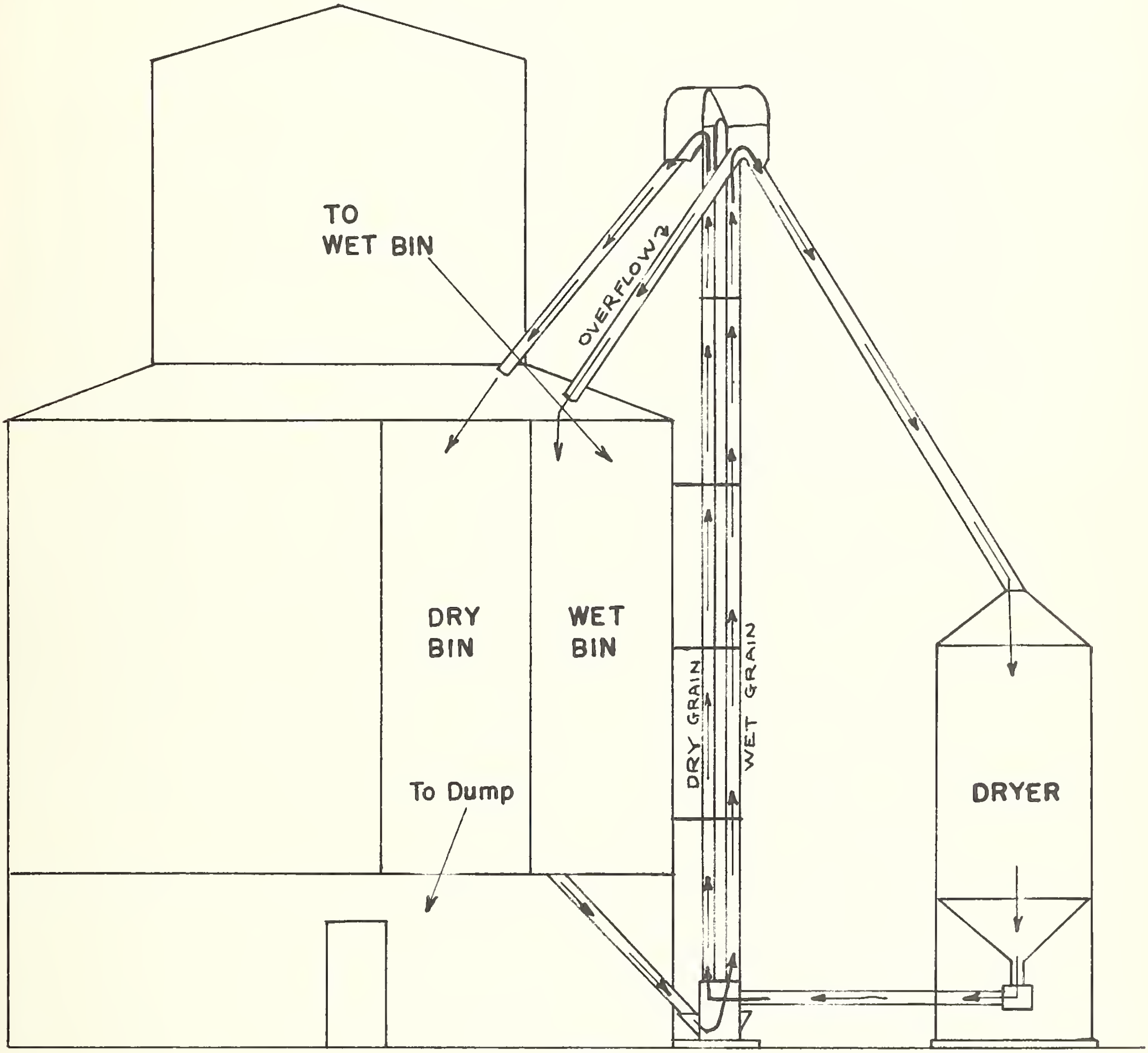
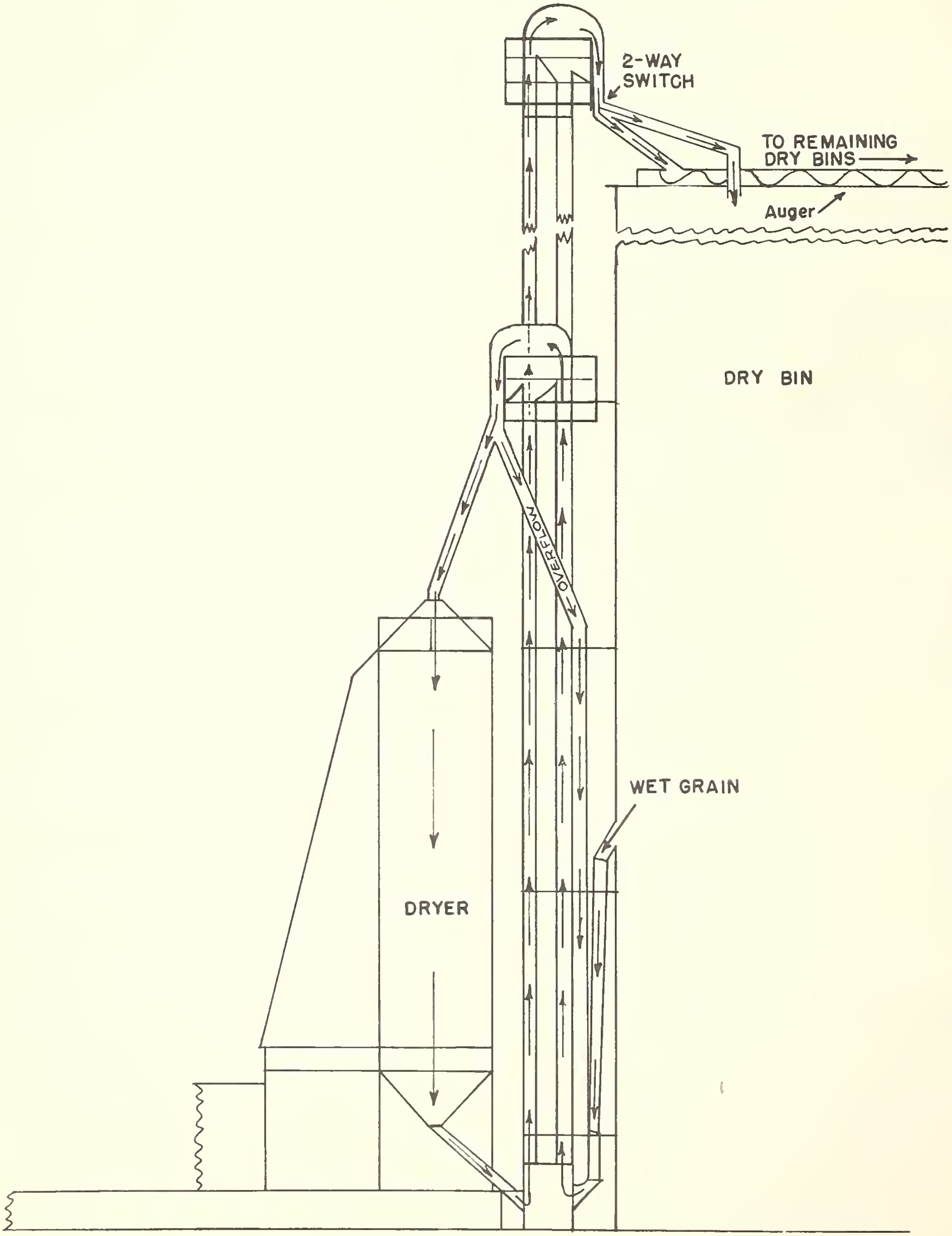


Figure 11

Type of Dryer Installation Used for Larger Continuous-Flow Grain Dryers at Kansas Elevators, 1957-58



Management Considerations in Drying Grain

A well managed grain drying operation starts with planning the layout and facilities to make daily activities as easy, economical, and efficient as possible. But the decision to receive grain too wet for safe storage creates many new situations and managerial problems, in addition to those related to providing physical facilities to take care of the grain.

Receiving wet grain involves (1) deciding what maximum moisture content to accept, (2) running tests for moisture, (3) computing allowances or charges for drying, (4) calculating the quantity of dry grain to credit to the farmer's account, and (5) deciding where to bin and how to handle and dispose of the wet grain.

It also means greater care in calculating shrinkage, in order to keep the elevator's grain position reflecting accurately grain stocks on hand. When grain is not dried, only shrinkage of grain while in storage must be calculated. When grain is received wet and artificially dried, the original and final moisture of the grain, as well as storage shrink, must be considered in calculating the grain position.

During harvest, receiving problems may be intensified with grain coming in so fast that lines are waiting at the scales. Often farmers are in such a hurry to unload that they wait only for the grain to be weighed and dump it before moisture tests are completed. This means that elevator employees must be competent to feel and observe the grain and decide whether to bin it as wet or dry. Where an elevator has but one dump pit, grain receiving is slowed down.

Receiving also may be complicated if the wet grain is being segregated by moisture ranges. Some elevators segregate grain above 18 percent moisture content from that which is below 18 percent but still above the level of dry grain. When more than one kind of grain is being received in volume simultaneously, this creates further demands on receiving facilities.

When wet grain is coming in faster than drying facilities can take care of it or it can be disposed of by other methods, obviously the grain must be held in temporary storage. This calls for close attention to prevent losses occurring from grain going out of condition. It also calls for ingenuity in taking advantage of any opportunities to dispose of the grain advantageously by methods other than drying.

Minimizing Drying Costs

Keeping drying costs as low as possible is an important managerial function. Efforts to encourage a high volume of grain receipts probably have a greater influence than any other factor on keeping per-bushel direct drying costs to a minimum. During 1957-58, when the volume of grain dried in Kansas was indicated to be at an all-time high, direct drying costs were low. In years when there has been little need for grain drying, per-bushel costs have no doubt been higher. In promoting more volume, direct drying charges for custom drying should be kept as low as direct costs will permit. This will encourage farmers to dry more grain and will strengthen the trend towards earlier harvest.

As explained earlier in this report, annual ownership costs for a particular

dryer are pre-fixed in total amounts but generally rise as the capacity or size of dryer is increased. This means that dryer size should be carefully correlated with needs to keep grain drying costs to a minimum. However, the trend toward more grain drying requires that future needs and long-run costs be considered.

Plant layout and bin arrangements that permit easy drying operations with little disruption to other elevator activities will help keep drying costs low. Poorly planned facilities lead to extra handling, create bottlenecks, and thus cause costs to be higher than necessary.

Labor Needs

Operating a dryer does not require one man's full time and attention. Therefore, labor costs are lower if drying is done during the regular working day when one employee can take charge of the dryer and also help with other elevator activities. As many as two men were reported to be needed full time on the dryer to promote fire safety when it was necessary to dry at night, compared with as little as 20 percent of one man's time reported used to operate the dryer during the day.

However, there are times when the demand for drying is so concentrated that it is more profitable to the overall operation to dry around the clock, even though per-bushel labor costs of drying are increased. Sometimes making maximum use of facilities to receive the farmer's grain during harvest rush periods and putting wet grain in condition to store safely are more important factors than drying costs.

Determining Drying Rate

Some dryer operators believed it was uneconomical and expensive to try to drop the moisture content of grain more than about five percentage points at one pass through the dryer.

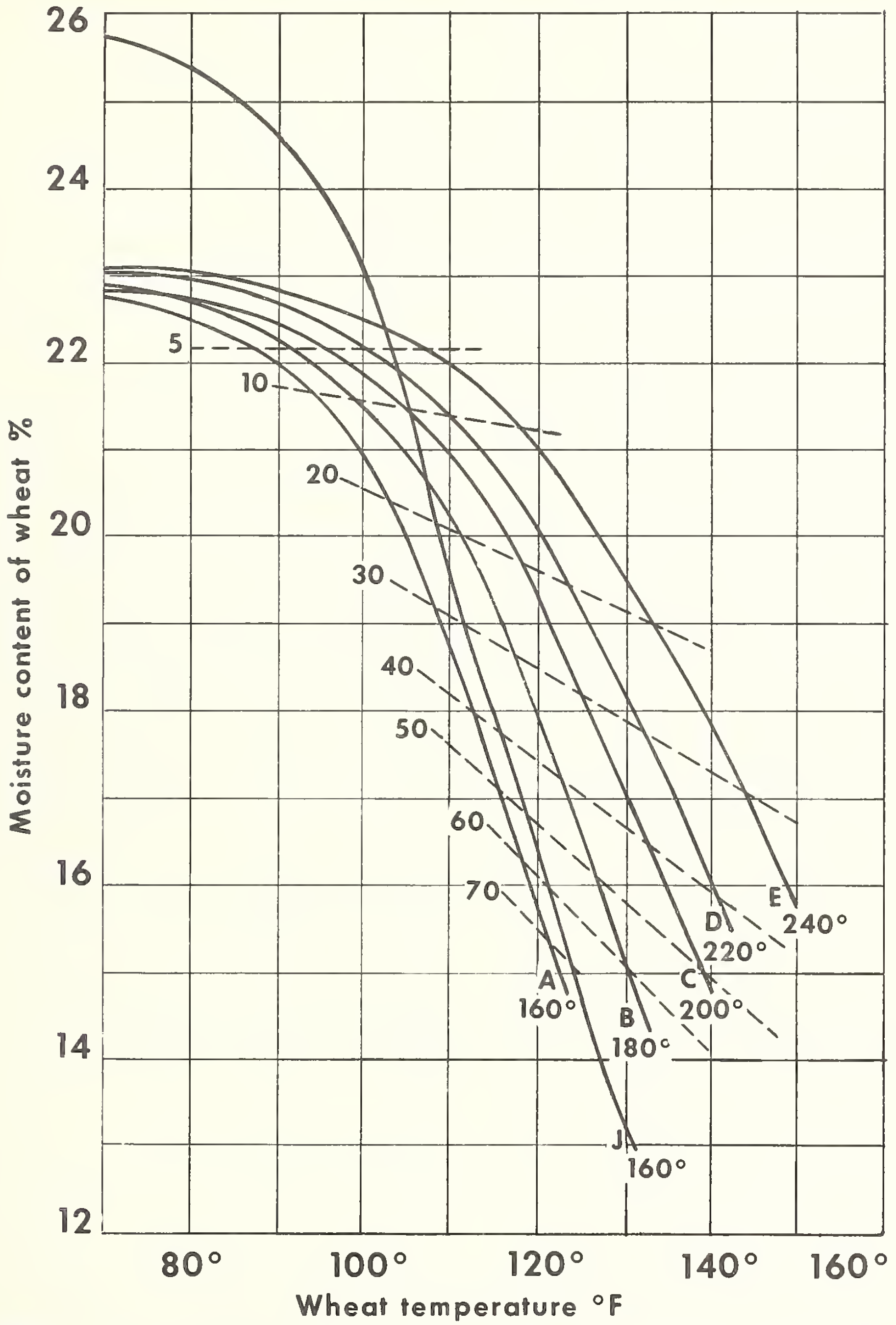
Research *(15)* shows that drying rates slow down as the length of drying time increases, especially when the moisture content approachs that of dry grain (figure 12). Also shown in figure 12 is the relationship between moisture content of wheat, time of drying, and grain temperature when the drying air temperature was varied and other factors including amount of air blown through the grain were held constant. After the first 5 minutes of drying time, as shown in figure 12, the intervals between the short broken lines are the same, or 10 minutes, but the vertical distances between them, measuring the drop in moisture content of the grain, decrease as the total drying time increases. That is, the drop in moisture each succeeding 10 minutes is less, the longer the grain is in the dryer.

Data from daily reports on drying grain at six of the study elevators support the conclusion that the wetter the grain is, the faster it loses water during the drying process (table 15 and appendix table 10).

These tables show that the rate of drying was faster when the original moisture of the grain was highest and appendix table 10 gives some support to the contention that drying grain more than once may increase the drying rate when the original moisture content is relatively high. With the air temperature, air flow rate, and input factors unchanged, the hourly cost of operating a given dryer will remain approximately the same. Therefore, an increase in drying rate brought about by other means than varying the input factors will tend to reduce per-bushel drying costs.

Figure 12

Drying Air and Wheat Temperature, Moisture Content and Drying Time Related



NOTE: Air temperatures are given in chart for each line. Broken short lines indicate drying time in minutes. Source: The Drying of Wheat II The Drying of English Wheat, By Moundfield, J.D., Halton, P., and Simpson, A. G.; Journal of the Society of Chemical Industry, April 1944.

Table 15. - *Rate of drying grain shown as an index and related to moisture content for six Kansas local elevators, 1957-58*

Kind and amount of grain	Average moisture content: Original[1]	Average moisture content: Final	Index[2] of moisture removed per hour
	Percent	*Percent*	
Sorghum grain:			
306,024 bu.	15.3	12.5	100
137,837 bu.	16.9	13.4	104
55,081 bu.	19.8	14.7	153
Corn:			
10,800 bu.	15.6	12.1	100
13,514 bu.	17.2	12.5	143
3,512 bu.	19.1	11.9	155

[1]The ranges of original moisture content for each group were: 16.0 percent and below; 16.1 percent - 18.0 percent; and 18.1 percent and above.
[2]Indexed because of variation in size and type of dryers used. The index is weighted by the bushels of grain dried by each dryer and by letting the drying rate of the low moisture group equal 100.

However, if total drying costs are to be lowered, the reduction in per-bushel costs of operating the dryer must counteract the increased costs for additional elevations of grain to run it through the dryer more than once. The rate of drying may be important to the problem of establishing equitable charges for drying grain of varying moisture content.

Establishing Charges

Drying charges, shrinkage, and commercial discounts for wet grain form a nucleus of important factors for management to watch in operating a grain dryer. Charges should equal the real costs of drying if the operation is to pay its way. However, if they exceed the costs by much this will tend to discourage farmers from drying, or may encourage installation of excessive drying capacity during periods of heavy receipts of wet grain.

Shrinkage must be calculated carefully if the elevator is to avoid a short grain position and a hidden cost. Over-allowance for shrinkage will give the elevator a hidden charge, in a sense, for drying the grain and thus be as misleading as under-allowance.

Commercial discounts for high moisture grain are a means for discouraging the harvesting of excessive amounts of wet grain. However, to the extent they exceed shrinkage costs and direct drying costs or charges, they encourage artificial drying of any grain marketed wet (see earlier discussion under "The Farmer's Decision on Whether to Dry Grain").

Drying Charges

Drying charges at the 11 elevators studied generally were governed by kind of grain and original moisture content. Only two of these elevators had exactly the same schedule of drying charges for wheat (appendix table 11). There were basically seven schedules of charges. One elevator made no charge for drying or for shrinkage, and one

dried no wheat. Usually there were also variations in charges made for drying corn, sorghum grain, barley, and oats.

Of the eight dryers that made a cash charge for drying grain, five charged on the number of bushels of wet grain, and three used the weight after drying. One other credited the farmer with wet bushels and charged for drying by discounting the wet bushels at 1 cent for each 1/4 percent moisture exceeding 13 percent. That charge was made to cover both direct drying costs and shrinkage.

Sometimes a farmer wants to have grain dried to return to the farm. Unless the elevator has numerous small bins, it is often impractical to return the farmer's own grain to him. Usually it is necessary for the elevator to take the farmer's wet grain and return dried grain of equal kind and quality. Six of the study elevators did not exchange dry grain for wet grain. Of the five that did exchange grain, one charged 2 cents a bushel for handling.

The variations in drying charges indicate differences of opinion as to costs and as to the importance of recovering the full costs of drying, but not much in excess, from those using the service. Unless charges for drying at least equal costs, those using other elevator services may actually be subsidizing the grain drying. If, however, the charges far exceed real costs, which are difficult to predetermine because volume to be dried is indefinite, those drying grain may be subsidizing other services. This problem is particularly important to cooperative elevators because in a cooperative each patron shares in benefits in proportion to his patronage or contribution.

Unquestionably, it is a problem to establish a schedule of per-bushel charges for drying grain of varying original moisture content that will maintain a fixed relationship between charges and direct drying costs. However, unless drying charges and direct drying costs vary together, the charges may prove to be inequitable.

Six elevators made daily drying reports for sorghum grain. Appendix table 12 shows the variation in drying rates related to original moisture content and the charges per bushel. It also shows that in each instance there was variation in hourly drying revenue. Essentially, it indicates that to keep hourly drying revenue constant, charges for drying high moisture grain would need to be reduced or rates would need to be raised for drying grain in the lower moisture ranges.

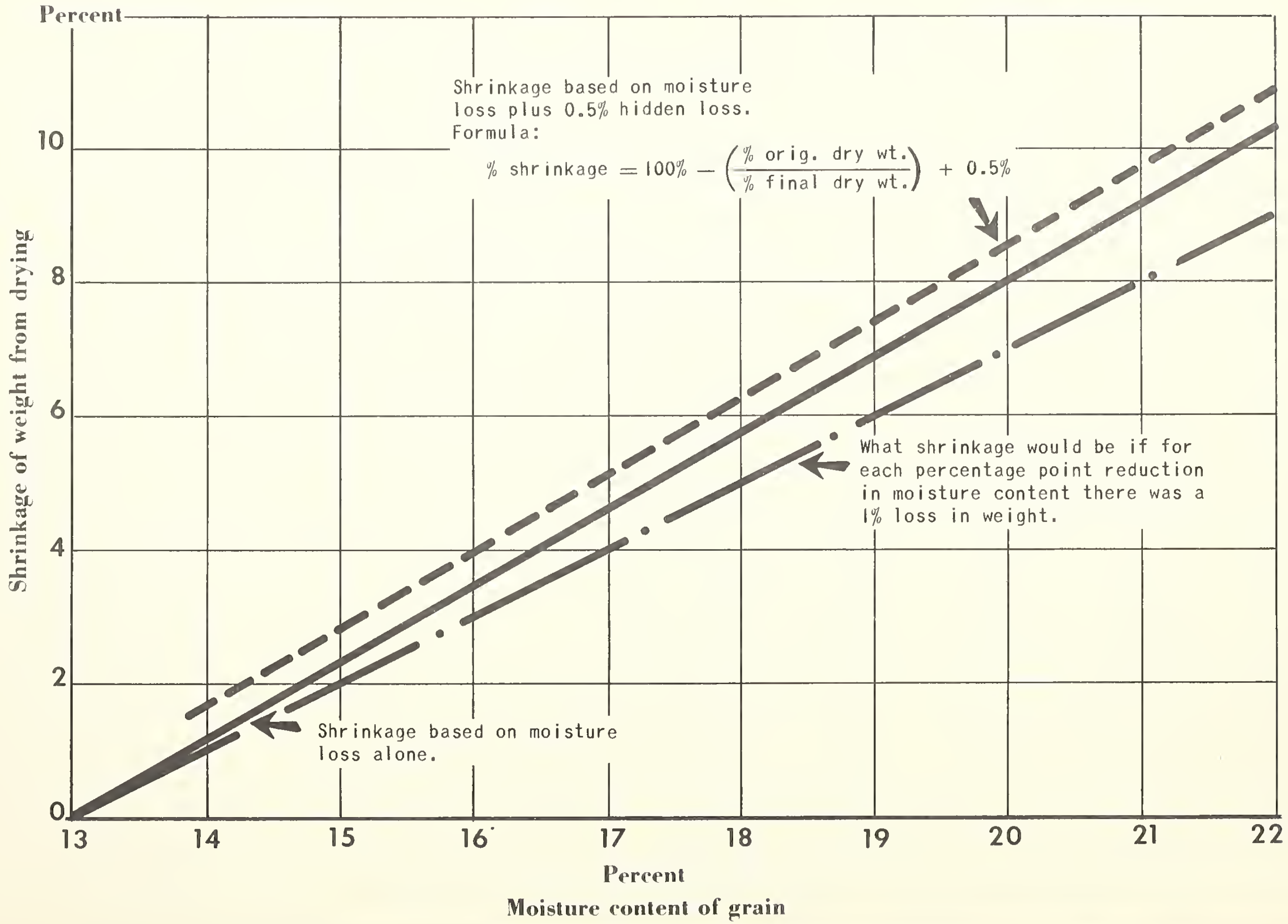
Shrinkage

Shrinkage in grain weight from drying is the result of moisture loss plus any loss of material that occurs. Moisture content of dried grain is a percentage of a lighter weight than the original wet grain. Therefore, the shrinkage caused by moisture loss is a greater percentage of the original weight than the reduction in percentage points of moisture removed in drying (appendix table 13).

The relationship of these percentages is shown graphically in figure 13. For example, for grain dried from 18 to 13 percent moisture, the points reduced are five. The shrinkage based on moisture loss alone is 5.75 percent of the original grain weight. Including an assumed 0.50 percent hidden loss, the total shrinkage is 6.25 percent of the original grain weight.

Figure 13

The Relationship Between Moisture Content Reduction of Grain Dried And the Percentage of Original Weight Lost as Shrinkage



If total shrinkage data based on weights before and after drying and accurate moisture determinations are available, shrinkage from loss in weight other than moisture loss can be easily determined. Accurate determinations of moisture content before and after drying permit the weight loss from moisture loss alone to be computed easily and accurately by mathematical procedure. The formula is as follows: Moisture shrinkage equals 100 percent of original weight, minus the original percentage moisture content (100 percent original weight minus original percentage moisture content) divided by the percentage dry matter after drying (100 percent final weight minus final percentage moisture content).

Moisture Shrinkage =

$$100\% - \frac{100\% - \text{original percentage moisture}}{100\% - \text{final percentage moisture}}$$

After moisture shrinkage is determined by this formula, the hidden shrinkage can be determined by deducting moisture shrinkage from the total shrinkage by weight.

Managers of drying operations in this study used various methods to determine the amount of grain to credit the farmer. These ranged from deducting nothing for shrinkage to deducting as much as 2 percent of the original weight for each percentage point the moisture content was reduced in drying the grain. Most of the elevators determined shrinkage by using a chart based on the formula *(17)*. To this shrinkage they added an assumed percentage for hidden loss.

Any over-drying of grain will result in unnecessary shrinkage, as was discussed earlier in the section "The Farmer's Decision Whether to Dry Grain." Also, an error in moisture determinations of the grain samples or failure of the samples to be representative of the lot of grain will cause errors in shrinkage determinations that are not based on actual weight.

Moisture Discounts

Commercial discounting of prices paid for grain that is higher in moisture content than desired for safe storage has been common practice in the grain trade. However, the terminal elevator usually will receive only limited amounts of wet grain. The discount is varied to influence the amount of wet grain offered.

The moisture discount made at the terminal provides the margin for a local elevator that has a grain dryer to meet direct drying and shrinkage costs for the wet grain that it purchases.

Quality and Marketing Considerations

Marketability or trade acceptance of grain depends not only on its quality, but also on whether the trade can reliably determine its quality by observing its market grade factors. If certain treatment of grain makes its quality questionable or difficult to determine, the portion of the supply thus treated naturally may be discriminated against in the market.

There appears to have been some market discrimination against artificially dried grain. This is evidenced by opposition to buying any dried grain rather than by price difference, excluding instances when the dried grain is visibly damaged.

Opposition to buying dried grain is more apt to occur when the grain is to be used for milling purposes, especially corn for wet milling. However, the fact that some wet corn millers operate

grain dryers indicates that corn dried under controlled conditions is satisfactory for this use. The main reason they do not like to buy artificially dried corn is that there is no premilling test to determine whether corn has been properly or improperly dried *(5)*.

Some discrimination against buying artificially dried wheat for milling purposes appears to be just a matter of precaution. As one flour miller put it, "Why take a chance on artificially dried grain when there is plenty of naturally dried grain available ?"

The important precaution to take in avoiding injury to grain quality while drying is to keep the grain temperature below certain limits, which may change as other factors vary, *(2, 3, 4, 7, 15, 18.)*. The critical grain temperature differs by kind of grain and by its intended use. Research evidence also indicates that it varies with conditions under which the grain is dried.

Appendix Table 1. - *Average cost of drying 325,000 bushels of grain*[1] *per dryer at 10 Kansas local elevators, August 1957-July 1958, and projected average costs*[1] *for drying varying average annual volumes*

Cost items	Cost for volume dried[2] 1957-58		Projected costs at various average annual volumes dried per dryer											
			16,250 Bu.		32,500 Bu.		81,250 Bu.		162,500 Bu.		650,000 Bu.		975,000 Bu.	
	Total	Per bu.	Total	Per bu.	Total	Per bu.	Total	Per bu.	Total	Per bu.	Total	Per bu.	Total	Per bu.
	Dollars	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*	*Dollars*	*Cents*
Fixed costs:														
Depreciation	945	0.29	945	5.82	945	2.91	945	1.16	945	0.58	945	0.14	945	0.10
Taxes	107	0.03	107	0.66	107	0.33	107	0.14	107	0.07	107	0.02	107	0.01
Insurance	124	0.04	124	0.76	124	0.38	124	0.16	124	0.08	124	0.02	124	0.01
Interest	381	0.12	381	2.34	381	1.17	381	0.46	381	0.23	381	0.06	381	0.04
Total fixed costs	1,557	0.48	1,557	9.58	1,557	4.79	1,557	1.92	1,557	0.96	1,557	0.24	1,557	0.16
Variable costs:														
Labor	925	0.28	46	0.28	92	0.28	231	0.28	463	0.28	1,850	0.28	2,775	0.28
Repairs and maintenance	99	0.03	5	0.03	10	0.03	25	0.03	50	0.03	198	0.03	297	0.03
Fuel	1,213	0.38	61	0.38	121	0.38	304	0.38	606	0.38	2,426	0.38	3,639	0.38
Electric power	496	0.15	25	0.15	50	0.15	124	0.15	248	0.15	992	0.15	1,488	0.15
Administrative	497	0.15	25	0.15	50	0.15	124	0.15	248	0.15	994	0.15	1,491	0.15
Total variable costs	3,230	0.99	162	0.99	323	0.99	808	0.99	1,615	0.99	6,460	0.99	9,690	0.99
Total direct drying costs	4,787	1.47	1,719	10.57	1,880	5.78	2,365	2.91	3,172	1.95	8,017	1.23	11,247	1.15
Shrinkage costs[3]	13,299	4.09		4.09		4.09		4.09		4.09		4.09		4.09
Total costs	18,086	5.56		14.66		9.87		7.00		6.04		5.32		5.24

[1]Based on reducing the moisture from 16.3 to 12.6 percent (table 2).
[2]The 10 dryers averaged 325,000 bushels; the range was from 45,387 to 1,501,900 bushels.
[3]Based on the formula: Shrinkage = 100% original weight - $\left(\frac{\text{original dry matter \%}}{\text{final dry matter \%}} + 0.5\%\right)$. Shrinkage is weighted by bushels shown in table 2 and valued at the monthly prices received by Kansas farmers computed from Agricultural Prices, Agricultural Marketing Service, U. S. Department of Agriculture.

Appendix table 2. - *Grain dried, drying rate, and moisture content of grain dried, by size and type dryer, at 10 Kansas local elevators, August 1957-July 1958*

Size and type of dryer[1]	Grain dried		Moisture content[3]	
	Total	Per hour[2]	Original	Final
	Bushels		*Percent*	
500-bu. Batch (holding capacity)	473,869	205	17.0	12.4
125-bu. Continuous flow	230,747	167	18.2	12.9
300-bu. Continuous flow	739,189	228	16.3	12.5
600-bu. Continuous flow	1,806,900	458	15.9	12.6

[1]Three batch dryers, two each of the 125 and 600-bushel continuous flow dryers, and three of the 300-bushel continuous flow.
[2]Partially estimated.
[3]Weighted by bushels.

Appendix table 3. - *Average fuel cost per bushel of grain dried at 10 Kansas local elevators using natural gas or propane, August 1957-July 1958*

Kind of fuel used	Dryers in group	Grain dried		Moisture content		Fuel cost per bushel
		Total	Average per dryer	Original	Final	
	Number	*Bushels*		*Percent*		*Cents*
Natural gas	6	2,731,458	455,243	16.1	12.6	[1]0.31
Propane	4	519,247	129,812	17.7	12.9	0.71

[1]When the points of moisture reduction for the dryers using natural gas were increased to equal the reduction for the dryers using propane, their fuel cost was estimated to be 0.42 cent per bushel.

Appendix table 4. - *Weight loss (shrinkage), discount, and shrinkage cost schedules for drying grain of various moisture content at various prices for dry grain*

Original moisture content of grain	Weight loss[1] in drying to 13%	Discount per bushel at these rates for each percent of moisture above 13%				Shrinkage cost per original bushel resulting from drying to 13 percent moisture at specified prices per bushel for grain of 13 percent moisture content[2]						
		at 1¢	at 2¢	at 4¢	at 6¢	$0.50	$0.75	$1.00	$1.25	$1.50	$1.75	$2.00
Percent		*Cents*				*Cents*						
13	0	0	0	0	0	0	0	0	0	0	0	0
14	1.65	1	2	4	6	0.82	1.24	1.65	2.06	2.48	2.89	3.30
15	2.80	2	4	8	12	1.40	2.10	2.80	3.50	4.20	4.90	5.60
16	3.95	3	6	12	18	1.98	2.96	3.95	4.94	5.92	6.91	7.90
17	5.10	4	8	16	24	2.55	3.82	5.10	6.38	7.65	8.92	10.20
18	6.25	5	10	20	30	3.12	4.69	6.25	7.81	9.38	10.94	12.50
19	7.40	6	12	24	36	3.70	5.55	7.40	9.25	11.10	12.95	14.80
20	8.55	7	14	28	42	4.28	6.41	8.55	10.69	12.82	14.96	17.10
21	9.70	8	16	32	48	4.85	7.27	9.70	12.12	14.55	16.98	19.40
22	10.84	9	18	36	54	5.42	8.13	10.84	13.55	16.26	18.97	21.68
23	11.99	10	20	40	60	6.00	8.99	11.99	14.99	17.98	20.98	23.98
24	13.14	11	22	44	66	6.57	9.86	13.14	16.42	19.71	23.00	26.28
25	14.29	12	24	48	72	7.14	10.72	14.29	17.86	21.44	25.01	28.58
26	15.44	13	26	52	78	7.72	11.58	15.44	19.30	23.16	27.02	30.88
27	16.59	14	28	56	84	8.30	12.44	16.59	20.74	24.88	29.03	33.18
28	17.74	15	30	60	90	8.87	13.30	17.74	22.18	26.61	31.04	35.48
29	18.89	16	32	64	96	9.44	14.17	18.89	23.61	28.34	33.06	37.78
30	20.04	17	34	68	102	10.02	15.03	20.04	25.05	30.06	35.07	40.08
31	21.19	18	36	72	108	10.60	15.89	21.19	26.49	31.78	37.08	42.38
32	22.34	19	38	76	114	11.17	16.76	22.34	27.92	33.51	39.10	44.68
33	23.49	20	40	80	120	11.74	17.62	23.49	29.36	35.24	41.11	46.98
34	24.64	21	42	84	126	12.32	18.48	24.64	30.80	36.96	43.12	49.28

[1] Includes 0.5 percent hidden loss.
[2] Applies to any grain regardless of weight per bushel.

Appendix table 5. - *Daily cash prices*[1] *at Kansas City, June 1 - July 18, 1958, on number 2 Hard and Dark Red Winter Wheat*

Date	Range of prices		Date	Range of prices	
	Low	*High*		*Low*	*High*
June			July		
2	$2.15	$2.30 1/4	1	$1.69	$1.82 1/4
3	2.05 3/4	2.09 3/4	2	1.71 1/2	2.04 3/4
4	2.10	2.10	3	1.74	1.95 1/2
5	2.07 1/4	2.07 1/4	7	1.75	1.92 1/2
6	2.09 1/4	2.09 1/4	8	1.76 1/4	1.91
9	*1.98 1/2	*2.37 1/2	9	1.76 1/2	1.89
10	1.97 3/4	1.97 3/4	10	1.76 1/4	2.00 3/4
11	*1.97	*2.37	11	1.78	2.07 1/2
12	*1.97 3/4	*2.38 1/2	14	1.79	2.00 1/4
13	*1.99	*2.38 1/2	15	1.80 1/4	1.90
16	*1.92 3/4	*2.32 3/4	16	1.82	2.00 1/4
17	1.90	1.94 1/4	17	1.83 1/2	2.07 1/2
18	1.91 3/4	1.91 3/4	18	1.83 1/4	2.09
19	1.91 1/2	1.91 1/2			
20	1.92 3/4	2.00 3/4			
23	1.91 1/4	1.94 1/4			
24	1.85 1/2	1.93			
25	1.87	1.92 1/2			
26	1.79 1/4	1.79 1/4			
27	1.77 3/4	1.88 1/2			
30	1.73 3/4	1.89 1/2			

[1]Source: Annual Statistical Report, 1958, Kansas City Board of Trade.

*Nominal, apparently not based on actual transactions.

Appendix table 6. - *Grain produced and sold in Kansas, 1950-58*

Crop year	Grain volume[1]			Production based on 1945-54 average as 100 percent
	Produced	Sold		
	1,000 Bushels		*Percent*	*Percent*
1950	343,653	234,051	68	105
1951	263,711	180,426	68	80
1952	413,302	331,622	80	126
1953	254,901	177,312	70	78
1954	313,149	226,267	72	95
1955	243,385	166,344	68	74
1956	237,097	173,339	73	72
1957	327,582	220,670	67	100
1958	541,735	421,513	78	165

[1]Includes corn, wheat, oats, barley rye, sorghum grain and soybeans.

Source: Field and Seed Crops, Agricultural Marketing Service, Crop Reporting Board, U. S. Department of Agriculture.

Appendix table 7. - *Estimated[1] percentage of grain receipts artifically dried, at six Kansas local elevators 1953-57*

Grain	Crop year					
	1953	1954	1955	1956	1957	Average
	Percent					
Wheat	0.76	0.11	0.43	2.37	2.39	1.00
Corn	0.75	2.86	3.01	26.02	13.98	11.98
Oats	0	0	0	0	0	0
Sorghum grain	12.26	11.72	4.50	7.35	83.62	52.61
Barley	1.63	0	1.50	8.71	4.12	3.69
All grain	2.08	1.73	1.54	4.46	62.86	18.45

[1]Estimated by management of these elevators.

Appendix table 8. - *Average number of days with precipitation of .01 inch or more and the monthly means with deviations at four stations*[1] *in Kansas, 1953-57*

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Days						
1953	2	5	8	8	11	8	8	8	2	5	7	4
1954	3	2	4	4	11	5	6	9	3	6	0	4
1955	5	7	4	6	11	12	6	5	7	4	2	3
1956	6	4	4	5	8	5	11	8	2	4	4	5
1957	7	5	11	14	14	13	8	6	8	8	7	3
Mean	5	5	6	8	12	9	8	8	5	6	4	4
						Deviations from mean						
1953	-3	0	+2	0	-1	-1	0	0	-3	-1	+3	0
1954	-2	-3	-2	-4	-1	-4	-2	+1	-2	0	-4	0
1955	0	+2	-2	-2	-1	+3	-2	-3	+2	-2	-2	-1
1956	+1	-1	-2	-3	-4	-4	+3	0	-3	-2	0	+1
1957	+2	0	+5	+6	+2	+4	0	-2	+3	+2	+3	-1

[1]Stations at Topeka, Wichita, Dodge City, and Goodland.

Source: U. S. Dept. of Commerce, Weather Bureau.

Appendix table 9. - *Average relative humidity and the monthly mean with deviations at four stations*[1] *in Kansas, 1953-57*

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						Percent						
1953	71	57	58	59	62	54	63	58	44	57	72	72
1954	67	53	57	56	68	55	48	58	48	67	54	60
1955	73	73	53	50	62	67	54	54	56	56	54	66
1956	64	73	50	53	60	55	56	49	38	50	63	64
1957	70	68	70	72	74	70	62	62	66	73	71	58
Mean	68	68	62	61	67	65	60	59	56	63	62	68
						Deviation from mean						
1953	+3	-11	-4	-2	-5	-11	+3	-1	-12	-6	+10	+4
1954	-1	-15	-5	-5	+1	-10	-12	-1	-8	+4	-8	-8
1955	+5	+5	-9	-11	-5	+2	-6	-5	0	-7	-8	-2
1956	-4	+5	-12	-8	-7	-10	-4	-10	-18	-13	+1	-4
1957	+2	0	+8	+11	+7	+5	+2	+3	+10	+10	+9	-10

[1]Stations at Topeka, Wichita, Dodge City, and Goodland.

Source: U. S. Dept. of Commerce, Weather Bureau.

Appendix table 10. - *Rate of drying related to moisture content of sorghum grain, at one local elevator, Kansas, 1957-58*[1]

Range in original moisture content and times dried	Average moisture		Amount of grain dried			Moisture removed per hour of drying time
	Original	Final	Lots	Volume: Total	Volume: Per hour	
	Percent		*Number*	*Bushels*		*Pounds*
18.1 percent and above						
Once	18.8	12.2	3	3,610	146	615
Twice	18.5	11.8	1	897	92	402
Three times	20.0	11.9	17	35,354	135	716
Group total and average	19.8	11.9	21	39,861	134	697
16.1 - 18 percent						
Once	16.9	11.9	4	5,097	170	516
Twice	16.7	11.9	16	33,300	193	572
Three times	17.8	12.0	10	20,364	145	541
Group total and average	17.1	11.9	30	58,761	167	555
16 percent and below						
Once	15.6	11.9	15	22,020	229	556
Twice	15.6	11.8	9	17,640	199	491
Three times	None					
Group total and average	15.6	11.9	24	39,660	214	525
Grand total and average	17.4	11.9	75	138,282	168	599

[1]These data are from daily drying reports. The drying air temperature was not intentionally varied from 180° F., nor was the air flow changed.

Appendix table 11. - *Schedule of drying charges per bushel of wheat, corn, and sorghum grain dried at 11 Kansas local elevators, 1957-58*

Kind of grain and case study number[1]	Moisture content of dry grain	Charges per bushel for indicated original percentage moisture content as follows:[2]							
		13%	14%	15%	16%	17%	18%	19%	20%
	Percent	*Cents*							
Wheat:									
1	13	0	7	7	7	7	7	10	10
2	13		3.5	4	4.5	5	5.5	6	6.5
3	13		2	4	6	8	10	12	14
4	13		4	8	12	16	20	24	28
5	13		3	3	3	3	5	5	5
6	13		3	3	3	5	5	5	7
7	13		3	3	3	5	5	5	7
8	13		2	4	6	8	10	12	14
9	13	No charge made directly							
10	13		0	3	5	6	7	8	9
11	13	Does not dry wheat							
Corn:									
1	14	0	0	7	7	7	7	10	10
2	15		0	0	3.5	4.5	5.5	6.5	7.5
3		None dried - none received							
4		" " " "							
5	15		0	0	5	5	5	5	5
6	13		0	3	3	5	5	5	7
7	13		3	3	3	5	5	5	7
8	13		2	4	6	8	10	12	14
9		None dried							
10	13		0	3	5	6	7	8	9
11		None dried - none received							
Sorghum grain:									
1	13	0	7	7	7	7	7	10	10
2	12	3.5	4	4.5	5	5.5	6	6.5	7
3	12	0	4	6	8	10	12	14	16
4	13	0	4	8	12	16	20	24	28
5	13	0	5	5	5	5	5	5	5
6	13	0	3.9	3.9	3.9	3.9	3.9	5	6.2
7	13	0	3	3	3	5	5	5	7
8	13	0	2	4	6	8	10	12	14
9	13	0	2.2	4.5	6.7	9	11.2	13.4	15.7
10	13	0	2.8	2.8	2.8	2.8	4.5	5	5.6
11	13	0	[3]2%	6%	9%	12%	15%	18%	21%

[1]Notes following apply to the corresponding case study numbers in table.

(1) Grain under 19 percent moisture usually run once; 19 and above, twice. Charges were made on number times run and based on wet weight.

(2) Charges based on 3 cents to run plus 1/2 cent for each point of moisture to be removed. Charges based on wet weight.

(3) While the above was announced schedule, charges made per bushel were 10 cents for the first run and 5 cents for additional runs. Usually tried to drop moisture five percentage points each run. Charges based on dry weight.

(4) Charge based on wet weight; however, the farmer was credited with the wet weight of his grain. The charge included shrinkage cost as well as direct drying charge. Charges were computed on one-half percentage moisture content increments, beginning at 14 percent.

(5) Charges on wet weight of grain.

(6) Charges begin at 14.6 percent moisture content; based on dry weight. Sorghum grain dried was charged on a hundredweight basis; bushel charges are approximate.

(7) Same drying charges as for number six. Any grain returned to farm assessed a 2 cent handling charge.

(8) Charges calculated at 1 cent for each 1/2 percent moisture content exceeding 13 percent. Charges based on wet weight.

(9) Cooperative made no charge for drying wheat or for shrinkage. Sorghum grain dried was charged on a hundredweight basis; bushel charges are approximate.

(10) Charges based on wet weight. Sorghum grain charged on hundredweight basis; bushel charges are approximate.

(11) Charges were a percentage of the weight and included shrinkage. Direct drying charges were all in excess of the shrinkage.

[2]For grain above 20 percent, the charges followed the pattern of charges for grain below 20 percent moisture content.

[3]Percent of grain deducted for drying and shrinkage.

Appendix table 12. - *Sorghum grain drying charges related to grain moisture content and hourly dryer revenue at six Kansas local elevators, as reported in daily grain drying reports, 1957-58*

Dryer number and original moisture content of sorghum grain		Original amount of grain	Average moisture content		Grain dried per hour[1]	Revenue to dryer per hour	Drying charge per bushel[2]	Charges necessary to give constant revenue per hour for all moisture groups[3]
			Original	Final				
No.		*Bushels*	*Percent*		*Bushels*	*Dollars*	*Cents*	*Cents per bushel*
1	18.1% and above	7,920	21.1	12.5	77	7.70	10.00	10.00
	16.1% - 18.0%	2,946	17.3	12.1	84	5.88	7.00	9.17
	16.0% and below	3,324	15.3	11.6	105	7.35	7.00	7.33
3	18.1% and above	39,861	19.8	11.9	123	19.68	16.00	16.00
	16.1% - 18.0%	58,761	17.1	11.9	158	18.96	12.00	12.46
	16.0% and below	39,660	15.6	11.9	207	16.56	8.00	9.51
4	18.1% and above	None						
	16.1% - 18.0%	26,600	16.5	13.1	341	[4]34.86	[4]9.9	[4]9.9
	16.0% and below	61,155	15.4	12.4	463	[4]30.10	[4]6.5	[4]7.5
7	18.1% and above	10,500	19.1	11.6	168	8.40	5.00	5.00
	16.1% - 18.0%	38,000	16.9	11.9	214	10.70	5.00	3.93
	16.0% and below	13,000	15.2	11.4	258	7.74	3.00	3.26
8	18.1% and above	None						
	16.1% - 18.0%	49,876	16.6	13.0	279	19.53	7.00	7.00
	16.0% and below	58,904	15.6	12.5	344	17.20	5.00	5.68
10	18.1% and above	None						
	16.1% - 18.0%	13,828	17.4	12.5	280	12.54	4.48	4.48
	16.0% and below	3,914	15.7	11.6	309	8.65	2.80	4.06

[1] Wet weight except for numbers 3 and 7 which based charges on the dried grain weight.
[2] Schedules of charges are shown in appendix table 11. Charges were based on original moisture content averages above.
[3] These charges fix the revenue at the same rate as for the highest moisture group for each dryer individually.
[4] A percentage of the grain was taken to cover shrinkage and direct drying charges. Shrinkage was calculated and deducted from the total percentage taken to arrive at the percentage of grain weight taken to meet direct drying charges. Grain was valued at the loan rate of $1.60 per cwt. and applied to the grain taken to meet direct drying charges in determining the cents per bushel.

Appendix table 13. - *Shrinkage in percentage of original grain weight resulting from moisture lost in drying*

Moisture content of dried grain	Factors for calculating moisture loss[1]	Moisture loss in percentage of wet weight for grain of the following moisture percentages													
		13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	15.75	16.00	16.25	16.50
Percent		*Percent*													
10.00	1.11111	3.61	3.89	4.17	4.44	4.72	5.00	5.28	5.56	5.83	6.11	6.39	6.67	6.94	7.22
10.25	1.11421	3.34	3.62	3.90	4.18	4.46	4.74	5.01	5.29	5.57	5.85	6.13	6.41	6.69	6.96
10.50	1.11732	3.07	3.35	3.63	3.91	4.19	4.47	4.75	5.03	5.31	5.59	5.87	6.15	6.42	6.70
10.75	1.12045	2.80	3.08	3.36	3.64	3.92	4.20	4.48	4.76	5.04	5.32	5.60	5.88	6.16	6.44
11.00	1.12360	2.53	2.81	3.09	3.37	3.65	3.93	4.21	4.49	4.78	5.06	5.34	5.62	5.90	6.18
11.25	1.12680	2.25	2.54	2.82	3.10	3.38	3.66	3.94	4.23	4.51	4.79	5.07	5.35	5.63	5.92
11.50	1.13000	1.98	2.26	2.54	2.82	3.11	3.39	3.67	3.96	4.24	4.52	4.80	5.08	5.37	5.65
11.75	1.13320	1.70	1.98	2.27	2.55	2.83	3.12	3.40	3.68	3.97	4.25	4.53	4.82	5.10	5.38
12.00	1.13636	1.42	1.70	1.99	2.27	2.56	2.84	3.12	3.41	3.69	3.98	4.26	4.55	4.83	5.11
12.25	1.13962	1.14	1.42	1.71	1.99	2.28	2.56	2.85	3.13	3.42	3.70	3.99	4.27	4.56	4.84
12.50	1.14288	0.86	1.14	1.43	1.71	2.00	2.29	2.57	2.86	3.14	3.43	3.71	4.00	4.29	4.57
12.75	1.14614	0.57	0.86	1.15	1.43	1.72	2.01	2.29	2.58	2.87	3.15	3.44	3.72	4.01	4.30
13.00	1.14942	0.29	0.57	0.86	1.15	1.44	1.72	2.01	2.30	2.59	2.87	3.16	3.45	3.74	4.02
13.25	1.15276		0.29	0.58	0.86	1.15	1.44	1.73	2.02	2.31	2.59	2.88	3.17	3.46	3.75
13.50	1.15610			0.29	0.58	0.87	1.16	1.45	1.73	2.02	2.31	2.60	2.89	3.18	3.47
13.75	1.15944				0.29	0.58	0.87	1.16	1.45	1.74	2.03	2.32	2.61	2.90	3.19
14.00	1.16279					0.29	0.58	0.87	1.16	1.45	1.74	2.03	2.33	2.62	2.91
14.25	1.16621						0.29	0.58	0.87	1.17	1.46	1.75	2.04	2.33	2.62
14.50	1.16963							0.29	0.58	0.88	1.17	1.46	1.75	2.05	2.34
14.75	1.17305								0.29	0.59	0.88	1.17	1.47	1.76	2.05
15.00	1.17647									0.29	0.59	0.88	1.18	1.47	1.76
15.25	1.17997										0.29	0.59	0.88	1.18	1.47
15.50	1.18347											0.30	0.59	0.89	1.18

[1] These figures, when multiplied by the percentage points of moisture the grain is reduced in drying to the specified final moisture content, will give the percentage of the original weight lost through moisture reduction. They do not allow for any losses of drying resulting from any other loss such as dust, other foreign material, or grain kernels lost in the drying process. They apply to any grain regardless of weight per bushel. To find the moisture loss for grain higher than 20 percent in original moisture content, make the following calculations: Deduct the moisture content to which you expect to dry the grain (column one) from the moisture content of the wet grain and multiply the remainder by the factor for that moisture content of dried grain as given in column two. Example: Assume a lot of grain is dried from 24.10 percent to 13.00 percent moisture content. The remainder or difference is 11.10 points. Multiplying 11.10 by 1.14942, the weight lost as moisture alone, is 12.76 percent of the original grain weight.

Appendix table 13. - *Shrinkage in percentage of original grain weight resulting from moisture lost in drying - Continued*

Moisture content of dried grain	Factors for calculating moisture loss[1]	Moisture loss in percentage of wet weight for grain of the following moisture percentages													
		16.75	17.00	17.25	17.50	17.75	18.00	18.25	18.50	18.75	19.00	19.25	19.50	19.75	20.00
Percent		*Percent*													
10.00	1.11111	7.50	7.78	8.06	8.33	8.61	8.89	9.17	9.44	9.72	10.00	10.28	10.56	10.83	11.11
10.25	1.11421	7.24	7.52	7.80	8.08	8.36	8.64	8.91	9.19	9.47	9.75	10.03	10.31	10.58	10.86
10.50	1.11732	6.98	7.26	7.54	7.82	8.10	8.38	8.66	8.94	9.22	9.50	9.78	10.06	10.34	10.61
10.75	1.12045	6.72	7.00	7.28	7.56	7.84	8.12	8.40	8.68	8.96	9.24	9.52	9.80	10.08	10.36
11.00	1.12360	6.46	6.74	7.02	7.30	7.58	7.87	8.15	8.43	8.71	8.99	9.27	9.55	9.83	10.11
11.25	1.12680	6.20	6.48	6.76	7.04	7.32	7.61	7.89	8.17	8.45	8.73	9.01	9.30	9.58	9.86
11.50	1.13000	5.93	6.22	6.50	6.78	7.06	7.34	7.63	7.91	8.19	8.48	8.76	9.04	9.32	9.60
11.75	1.13320	5.67	5.95	6.23	6.52	6.80	7.08	7.37	7.65	7.93	8.22	8.50	8.78	9.07	9.35
12.00	1.13636	5.40	5.68	5.97	6.25	6.53	6.82	7.10	7.39	7.67	7.95	8.24	8.52	8.81	9.09
12.25	1.13962	5.13	5.41	5.70	5.98	6.27	6.55	6.84	7.12	7.41	7.69	7.98	8.26	8.55	8.83
12.50	1.14288	4.86	5.14	5.43	5.71	6.00	6.29	6.57	6.86	7.14	7.43	7.71	8.00	8.29	8.57
12.75	1.14614	4.58	4.87	5.16	5.44	5.73	6.02	6.30	6.59	6.88	7.16	7.45	7.74	8.02	8.31
13.00	1.14942	4.31	4.60	4.89	5.17	5.46	5.75	6.03	6.32	6.61	6.90	7.18	7.47	7.76	8.05
13.25	1.15276	4.03	4.32	4.61	4.90	5.19	5.48	4.76	6.05	6.34	6.63	6.92	7.20	7.49	7.78
13.50	1.15610	3.76	4.05	4.34	4.62	4.91	5.20	5.49	5.78	6.07	6.36	6.65	6.94	7.23	7.51
13.75	1.15944	3.48	3.77	4.06	4.35	4.64	4.93	5.22	5.51	5.80	6.09	6.38	6.67	6.96	7.25
14.00	1.16279	3.20	3.49	3.78	4.07	4.36	4.65	4.94	5.23	5.52	5.81	6.10	6.40	6.69	6.98
14.25	1.16621	2.92	3.21	3.50	3.79	4.08	4.37	4.67	4.96	5.25	5.54	5.83	6.12	6.41	6.71
14.50	1.16963	2.63	2.92	3.22	3.51	3.80	4.09	4.39	4.68	4.97	5.26	5.56	5.85	6.14	6.43
14.75	1.17305	2.35	2.64	2.93	3.23	3.52	3.81	4.11	4.40	4.69	4.99	5.28	5.57	5.87	6.16
15.00	1.17647	2.06	2.35	2.65	2.94	3.24	3.53	3.82	4.12	4.41	4.71	5.00	5.29	5.59	5.88
15.25	1.17997	1.77	2.06	2.36	2.65	2.95	3.24	3.54	3.83	4.13	4.42	4.72	5.01	5.31	5.60
15.50	1.18347	1.48	1.78	2.07	2.37	2.66	2.96	3.25	3.55	3.85	4.14	4.44	4.73	5.03	5.33

[1]See footnote on page 61.

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